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Shattered Earth: The Treatment of a Twentieth Century Clock and Globe

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1. Abstract

A clock and globe object produced c.1931 by the Universal Clock and Globe Corporation, was researched, analyzed and treated at the Buffalo State Art Conservation Department. The composite piece was both aesthetically and functionally compromised, having advanced polymeric decomposition and extensive metal corrosion. Research provided an historical context for the object, while also elucidating its technology and intended functionality. The material composition of the object was determined using a combination of microchemical testing, Fourier Transform infrared spectroscopy (FTIR), gas chromatography-mass spectrometry (GC-MS) and X-ray Fluorescence spectroscopy (XRF). The instrument's functionality was restored by reconstructing the highly degraded plastic components in polymethyl methacrylate (PMMA), and de-corroding the bound internal gear trains. Degraded electrical wiring was replaced to ensure that the device could be used safely. The most appropriate internal illumination source was determined by measuring the spectral power distribution for various LED and incandescent bulbs. Heavy tarnishing was reduced from the clock case and base, restoring its original surfaces. The fragile nitrocellulose globe was damaged during treatment, but was consolidated and strengthened with Paraloid B-67 resin and Cerex. Japanese tissue fills were used to compensate for losses to the globe gores.

2. Introduction

2.1 Object Overview

The Art Deco style globe/clock object was designed and produced by the 'Universal Clock and Globe Corporation' (Wilmington, Delaware) with a clock movement provided by the Warren Telechron Company, based in Ashland, Massachusetts. While the maker of the twelve inch plastic globe is unknown, the paper gores were supplied by Rand McNally. The metal frame and casing were die-cast by the Sterling Die-casting Co., of Brooklyn, New York. The gears for the globe's internal mechanism were produced by Boston Gear Company, and the lamp socket fixture was made by the Arrow- Hart & Hegeman Electric Company.

Both the clock and globe are mounted in a common support structure made from a zinc-based casting alloy. The Telechron clock is operated by a synchronous AC motor, which in turn powers the internal globe trains. Two wings fan out from the clock to support a circular ring, in which the globe is mounted, set on an angle of approximately 23 ½ degrees to the vertical. The circular ring is hinged such that the two inter-fitting globe hemispheres can be separated to access the inner workings of the globe which include a small incandescent bulb. The globe is geared to rotate one full revolution every twenty-four hours while accurately reflecting day and night at any given point in time around the world by way of its internal light source. In its original form the light bulb would have been shielded on one side so that only half of the globe was illuminated at any one time. This shielded light-source is set vertically, offset from the axis of the globe by 23 ½ degrees and is geared to revolve 1/365 of a revolution every day in order to show seasonal variation in the Earth's shadow.

Figure 1: *November 1930 National Geographic advertisement clipping for the Uniclok globe.*

The Uniclok instrument was marketed to consumers in the early thirties. A National Geographic advertisement for Uniclok from November 1930 describes a very similar timepiece (which has a different base, but otherwise is identical in appearance) in the following terms (see Figure 1):

> *"An electrical clock and chronological instrument which shows instantly the correct time all over the world, the period of day and night, the seasons, and position of the earth and sun in their proper relations to their respective orbits. The translucent globe is illuminated from within, realistically representing day and night throughout the world. The globe rotates on its axis once a day; the shadow revolves once a year, showing daylight, darkness, and the rotation of the seasons as they exist on the earth... Complete manual and textbook supplied with each Uniclok. They are sold by Telechron dealers and power company stores everywhere in the United States."*

Another advertisement for the Uniclok appeared a year later in the November issue of *The Literary Digest* (Funk and Wagnalls 1931) (see Figure 2). The model shown is identical to the object owned by the Buffalo Museum of Science (see Figure 3), indicating that the design of the base had changed within the year from hard-edged geometric forms to a more rounded and classically inspired molding. This evolution of design is also reflected in a technical drawing of the Uniclok globe included in paraphernalia related to silver-smithing once owned by American silver scholar, D. Albert Soeffing[1]. His collection now resides in the Winterthur Library, Winterthur, DE. The drawing also shows the more classical base consistent with the Buffalo Uniclok.

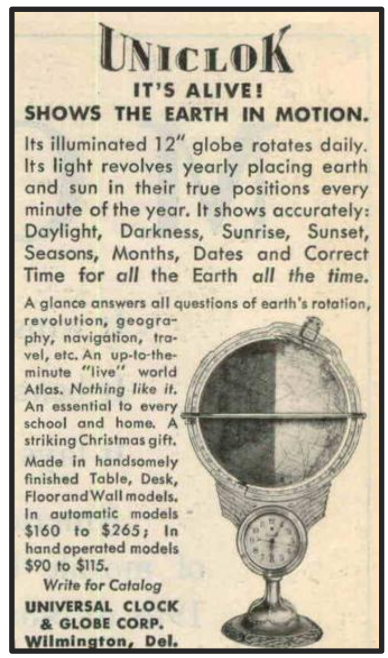

Figure 2: *An advertisement for the Uniclok globe shown in The Literary Digest from November 14, 1931. The globe is identical to the object that is the focus of this study.*

As stated in the National Geographic advertisement, the object was originally sold with a handbook titled: *The Earth : Uniclok Globe Handbook : A Pocket Manual of the Earth, Moon, Sun, Planets, Stars and…* authored by Herman E. Schulse. The booklet was both educational and promotional. While it enlightened the owner with relevant information about the earth, moon, sun and solar system, it also detailed the various features of the globe-clock, how to clean it, while also describing the various models and finishes in which the piece could be presented. Finishes included; 'Museum Bronze', 'Antique Bronze' and 'Antique Silver' (Schulse 1931). The handbook was an invaluable resource for this study as it also included

[1] The Winterthur Library, *"The Joseph Downs Collection of Manuscripts and Printed Ephemera"*, retrieved November 30th 2012: <findingaid.winterthur.org/html/HTML_Finding_Aids/COL0774.htm>

instructions for how to perform routine maintenance operations like changing the light-bulb in the globe interior.

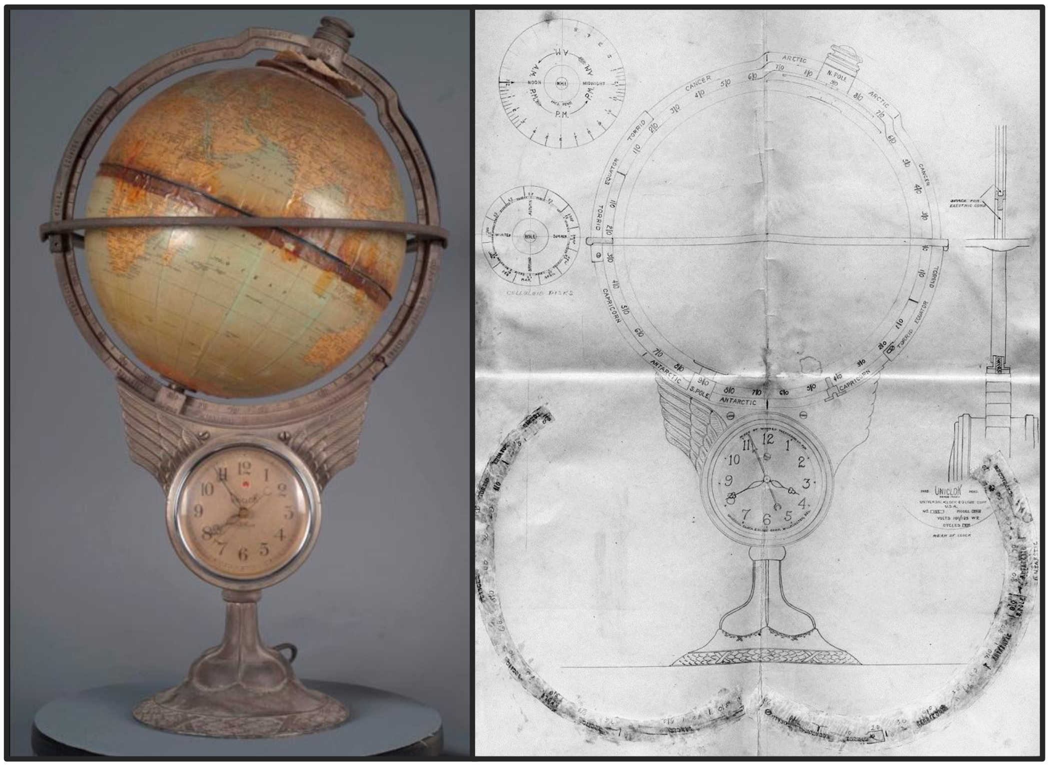

Figure 3: *Frontal image of the Uniclok owned by the Buffalo Museum of Science (normal illumination) compared to a greyscale image of the scanned drawing of a Uniclok delivered from the Winterthur Library[2]. Note: the design of the base is the same, and the drawing includes diagrams of the calottes in the upper left.*

2.2 Date of Manufacture

The object has key brand-name inscriptions, and copyright and patent indicators that strongly suggest a date range for its manufacture. These include the Warren Telechron Co. name on the clock face, and the "Pats. Pend." inscription on the clock verso.

The Telechron trademark (which was registered in December 1919[3]) is clearly seen on the clock face. Around the circumference of the clockface is a printed inscription that reads: "M.F.D BY WARREN TELECHRON CO. FOR UNIVERSAL CLOCK & GLOBE CORP. WILMINGTON. DEL." This indicates that the clock dates from after 1926, the year in which Warren's company changed its name from 'Warren Clock Co.', to 'Warren Telechron Co'(Linz 2001, 22).

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[2] The scan was acquired via email from Winterthur Librarian for the Joseph Downs Collection of Manuscripts and Printed Ephemera, Jeanne Solensky, on February 19th, 2013.

[3] Unknown, "Clocks by Warren Clock Co.", *www.clockhistory.com*, retrieved 28th October 2012. <clockhistory.com/telechron/warrenclockco/index.html >

The Universal Clock and Globe Corp, earned a copyright for the Uniclok device on July 14th 1931 (Library of Congress Copyright Office 1932, 998). This is however not the most reliable method for dating the object given that it could have easily gone in to mass production without a copyright being awarded.

The "Pats. Pend." inscription on the verso of the clock case suggests that multiple patents had been filed for the Uniclok but not yet granted when this device was manufactured. Patent 1,959,601 was awarded to a Herman E. Schulse of Wilmington, DE, the aforementioned author of the Uniclok handbook, for a 'Chronological Instrument' meeting the exact description of the object (see Figure 4). The application date of the patent was September 19th 1931 and the patent was awarded as of May 22nd 1934 (Schulse 1934). The object was most likely manufactured sometime between these two dates.

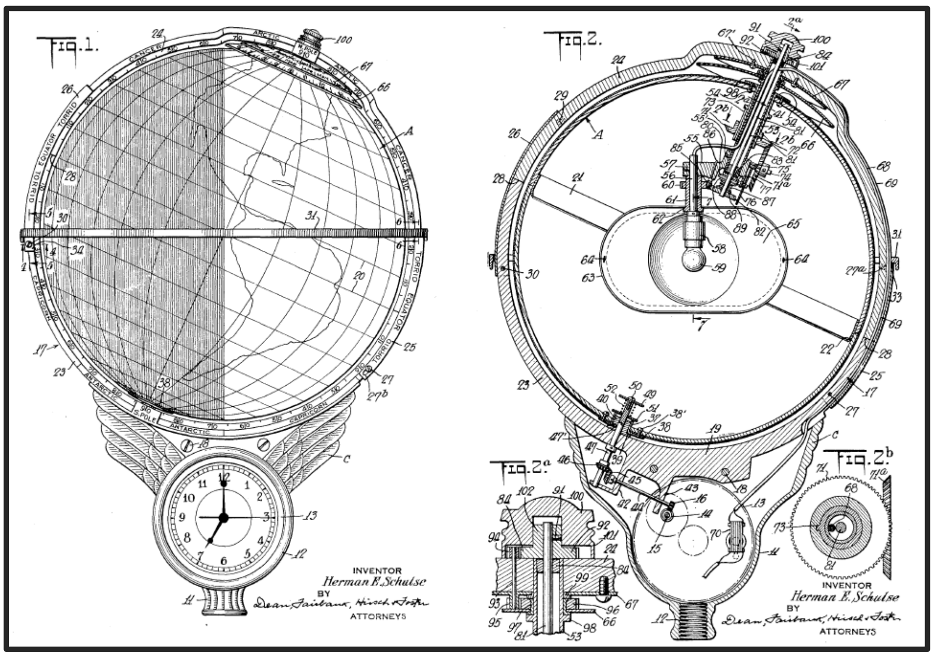

Figure 4: *Images from US Patent 1,959,601, awarded to Herman E. Schulse, showing a front view and cross section of his chronological instrument.*

2.3 Historical Context

A few examples of combination globe/clock timepieces were produced throughout the latter part of the nineteenth century by American clock smiths such as Louis P. Juvet, Theodore R, Timby, and LaPorte Hubbell.[4] All three makers produced globes that would rotate once every twenty-four hours and were driven by a spring powered clockwork movement (see figures 5 - 7).

Figure 5: *Juvet and Company Tabletop Globe Clock, c.1880.*

Figure 6: *Timby Solar Clock created by Theodore R. Timby in conjunction with Gilman Joslin, 1864.*

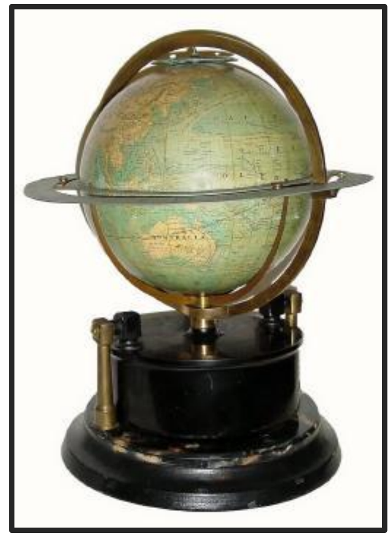

Figure 7: *Globe clock by The Globe Clock Company, Milldale, CT designed by LaPorte Hubbell, c.1883*

In 1880, *Scientific American* enthusiastically promoted Juvet's time globe as *"a fit ornament for any library, a valuable adjunct in every business office, and a necessity in every institution of learning."*[5] Not only were these kind of globes useful tools for studying geography, determining the time of day in other time-zones, and illustrating the rotation of the earth, they also gained a wider appeal as status symbols. Taking pride of place in the parlors and drawing rooms of Gilded Age America, these elegant time pieces demonstrated the wealth and culture of their owner.

The Universal Clock and Globe Corporation continued in this vein with their Uniclok design in the 1930s, but departed from the use of the traditional clockwork movement in favor of a new self-starting, synchronous clock mechanism developed in Ashland, Massachusetts, by the Warren Telechron Company. An electric powered clock was an

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[4] Antique Clocks: Antique Globe Clock Company Clock, retrieved February 21st 2013: <www.antiqueclockspriceguide.com/pages/clock6919.php>

[5] National Museum of American History, "Juvet Time Globe", *americanhistory.si.edu*, retrieved on February 21st 2013: <americanhistory.si.edu/collections/search/object/nmah_1203340>

interesting choice for the Uniclok object given that electric movements were eyed with suspicion in their early days of manufacture. The Universal Clock and Globe Corporation did however embrace a sense of the 'new' by using the Telechron technology, while also leveraging the ability to operate the clock and the translucent globe's internal light source using the same power source.

Electric clock movements were first considered as early as 1770, and were refined through several iterations until the twentieth century invention of a reliable synchronous AC motor which is used in the Uniclok object.[6] One of the earliest allusions to an electric clock was in astronomer James Ferguson's book *Introduction to Electricity*, where he included a plate showing an electrically driven clock and orrery (Aked, 1986). The first electrostatic pendulum clock was created in 1814 by Sir Francis Ronalds using a dry-pile battery. The first patented electric clock movement was introduced in 1841 by Alexander Bain (Aked, 1986), and used an electromagnetic field to drive its pendulum. Further experimentation and investigation into alternating current throughout the late nineteenth century by people such as Michael Faraday and Nikola Tesla led to the development of synchronous and asynchronous AC motors. The clock movement in the Uniclok was born out of these developments.

The Telechron self-starting synchronous electric motor was patented in 1918 by Henry E. Warren (1872-1957) (Linz 2001, 17), a prolific and celebrated inventor who died with over one hundred and thirty patents to his name. The motor relied on a consistent supply of alternating current operating at a frequency of sixty hertz in order to keep time. Electric utilities were notoriously inconsistent in managing their output frequency at this time, which had disastrous impact for the production and acceptance of early synchronous motor clocks. If the local power company was producing electricity at anything but an accepted and predictable number of cycles per second then the clocks would not keep accurate time. One of the most intriguing aspects to the Telechron story is the way in which Henry Warren tackled this problem. To ensure his clocks' commercial viability he created a governor, the Warren Master Clock, that he campaigned to have installed at his local power company, Boston-Edison, to act as a frequency regulator (Linz 2001, 13). The master clock had dual movements; one driven by a sixty hertz synchronous motor connected to the current produced by the power plant, the other driven by a traditional spring and pendulum mechanism. If the hands of the electric clock moved along perfectly with those of the 'traditional' clock, the power produced by the electric company was deemed to be of uniform

[6] After this time the refinement continued with the advent of the quartz clock, and its combination with solid state electronics which allowed quartz timekeepers to be significantly reduced in size.

frequency. If the movements were out of synch then the station operator could adjust the turbine governors on the generator to bring the hands back into accordance (Holcomb III, Webb 1985). To ensure the overall accuracy of the system the pendulum clock was synchronized twice a day with time signals received from the master clock at the US Naval Observatory. With Warren's master clock in place the utility was able to fulfill its promise of providing a predictable sixty-cycle alternating current power supply, and the Telechron clocks were able to achieve astonishing accuracy.

The impact of the Warren Master Clock was however more far reaching than time-keeping alone. By producing AC power at precisely the same frequency, power generating plants could transfer power to one another and efficiently hook together into a national grid system. Previously a power provider could only share electricity with another station by either first converting the power to DC before having it reconverted to AC at the receiving station, or by using an expensive frequency converter to facilitate the transfer. The Warren Master Clock was a more efficient and less costly alternative, and by 1925 more than four hundred of the devices were in use at electric utilities across the United States, and by 1947 they were responsible for the regulation of approximately ninety-five percent of the power produced in the USA (Linz 2001, 14). The subsequent impact of standardizing electrical output was that it created the ability to produce reliable and transportable consumer appliances. Prior to this, an appliance motor designed to work at the frequency of one generation plant could not be expected to work properly on the power grid of an alternate generation company.

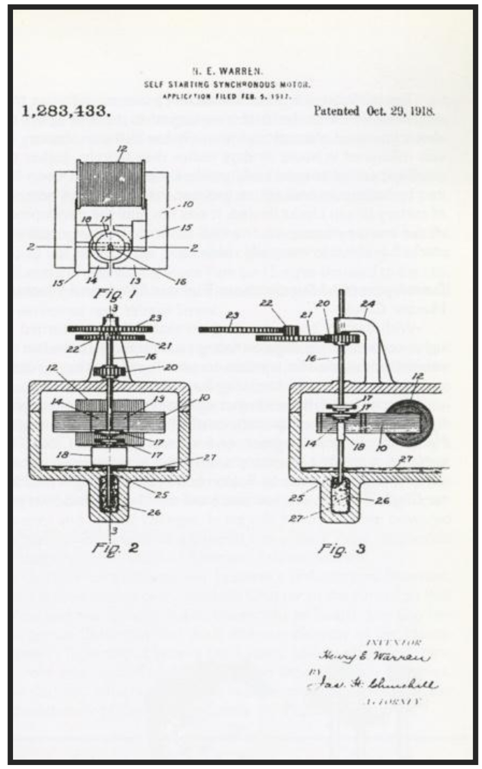


Figure 8: *A document, dated Oct 29 1918, awarding Warren the patent for a self-starting, synchronous motor.*

Telechron came of age in the Art Deco era and many of the early designs for their clocks incorporated Art Deco motifs and forms (see Figure 9). Moreover Telechron sought to combine modern engineering (including mass-production) with the beauty of simple geometric shapes which was one of the fundamental principles that we associate with the movement.[7] This may have been one of the principles that guided The Universal Clock and

[7] Wikipedia: The Free Encylcopedia, "Telechron", *www.wikipedia.org*, retrieved February 21st 2013: <en.wikipedia.org/wiki/Telechron>

Globe Corporation's choice to select Telechron as their timepiece manufacturer. The metal wings supporting the globe on the Uniclok object have a distinctive Art Deco appeal, so what better choice of partner than Warren's Telechron company to produce an Art Deco object given that they were at the cutting edge of horologic technology at that time?

Figure 9: *The Art Deco inspired Telechron Model 700 "Electrolarm", 1929-1931.*

Not a lot of information exists regarding the Universal Clock and Globe Corporation, other than their location in Wilmington, DE, and the identity of the Uniclok globe's designer, Herman E. Schulse, as indicated by the Uniclok's patent. It is known that the company produced at least one other electric clock in 1930 in conjunction with Haydon Manufacturing Co. Arthur William Haydon (1906-1982) was another inventor of synchronous electric clock movements and, although thirty-four years Warren's junior, was already actively producing clock movements in the late 1920s.

Two maker's marks inside the Uniclok casing (see inset image in Figure 10) show that its production was outsourced to Sterling Die-Casting Co., of Brooklyn, New York. The fact that the Universal Clock and Globe Corporation employed clock movements from multiple vendors, and did not manufacture the clock cases themselves, suggests that they may have been primarily in the business of designing and assembling their products.

Figure 10: *A series of images related to the Sterling Die Casting Co of Brooklyn, NY. Inset is an image of the maker's mark found on the object. The leftmost image is the exterior of the building at 743 39th Street, Brooklyn, NY. The central image shows the factory floor, while the rightmost image shows the finishing and packing room. A calendar on the back wall of this final image shows the month and year to be December, 1930. (Source: eBay.com, March 25th 2013).*

Herman E. Schulse's exact function within the Universal Clock and Globe Corporation is not clear, but he did apply for a number of patents related to mechanical features and designs for the Uniclok product from 1929 through 1931 (see table 1), and the fact that his name appears on the patent suggests that he was a key figure in the company's endeavors. The majority of the patents from this time period are related specifically to clock case designs (see Figure 11), which reinforces the theory that Universal Clock and Globe Corporation was focused more on producing the exterior of the clock than the timing mechanism itself.

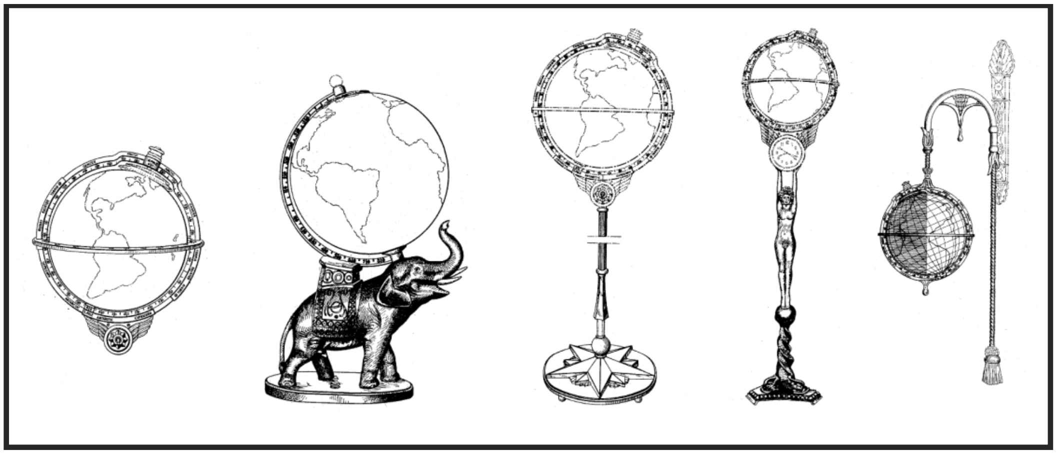


Figure 11: *Images from Schulse's design patents specifically related to clock cases and globe fixtures produced by the Universal Clock and Globe Corp. From left to right, with the US design patent numbers in parentheses: terrestrial globe frame (Des84,795), Rajah terrestrial globe support (Des84,796), 122-L terrestrial globe support (Des85,206), De Soto terrestrial globe and clock support (Des85,207) and a wall hanging globe fixture (Des86,937).*

Schulse's entire patent portfolio spans the period 1917 through 1956. A selection of Schulse's patents is listed in Table 1, and illustrates him as an inventor who was quite varied in his interests. At least nine of these patents relate directly to products sold by the Universal Clock and Globe Corporation, and two entries (patent 1,959,601 and design patent 84,794) are specifically related to the instrument owned by the Buffalo Museum of Science (Schulse 1931, 1934).

Table 1: *A selection of patents awarded to Herman E. Schulse including the filing date, dated awarded and patent number. The shaded entries are patents related to directly to the Universal Clock and Globe Corporation, and those in bold relate specifically to the Uniclok instrument owned by the Buffalo Museum of Science.*

Invention	Patent Filed	Patent Granted	US Patent #
Water Cooler	Dec. 2nd 1915	Jun. 5th 1917	1,228,836
Liquid Dispensing and Filtering Bottle	Jun. 20th 1916	Jun. 5th 1917	1,228,837
Apparatus for Manufacture of Filtering Films	Feb. 8th 1918	Oct. 12th 1920	1,355,292
Fibrous Filtering Film	May 28th 1918	Aug. 30th 1921	1,389,401
Process for Making Fibrous Filtering Films	Feb. 8th 1918	Oct. 11th 1921	1,392,989
Shoe Shine Installation	Oct. 29th 1927	Oct. 23rd 1928	1,688,753
Shoe Shine Seat	Jun. 5th 1928	Oct. 23rd 1928	Des 76,729
Dispensing Container	Oct. 17th 1927	Nov. 4th 1930	1,780,508
Shoe Shine Installation	Jan. 17th 1927	Oct. 27th 1931	1,828,820
Shoe Shine Last	Jun. 5th 1928	May 24th 1932	1,859,536
Flexible Shaft	Jul. 23rd 1928	Jun. 6th 1933	1,912,658
Terrestrial Globe Frame and Clock Casing	**Apr. 11th 1931**	**Aug. 4th 1931**	**Des 84,794**
Terrestrial Globe Frame	Apr. 11th 1931	Aug. 4th 1931	Des 84,795
Terrestrial Globe Frame and Support (Elephant “Rajah” Desk Model)	Apr. 11th 1931	Aug. 4th 1931	Des 84,796
Terrestrial Globe Frame and Support	Apr. 11th 1931	Aug. 18th 1931	Des 84,903
Terrestrial Globe Frame and Support (“122-L” Floor Model)	Apr. 11th 1931	Sep. 22nd 1931	Des 85,206
Terrestrial Globe Frame and Clock Casing Support (“De Soto” Floor Model)	Apr. 11th 1931	Sep. 22nd 1931	Des 85,207
Globe Fixture	Sep. 29th 1931	May 10th 1932	Des 86,937
Chronological Instrument	**Sep. 19th 1931**	**May 22nd 1934**	**1,959,601**
Chronological Instrument	Jul. 16th 1929	May 7th 1935	2,000,457
Beverage Conditioner and Dispenser	Dec. 28th 1934	Aug. 11th 1936	2,051,013
Bar Rinsing Equipment	Sep. 29th 1936	Dec. 22nd 1936	2,065,347
Beverage Dispensing Container	Sep. 9th 1933	Nov. 2nd 1937	2,098,210
Brew Cooling Device	Jul. 18th 1936	Nov. 2nd 1937	2,098,211
Brew Cooling Installation	Sep. 9th 1933	Nov. 28th 1939	2,181,710
Keg Cooling Installation	Jul. 18th 1936	Mar. 12th 1940	2,193,540
Brew Draft Equipment	Dec. 28th 1934	Apr. 9th 1940	2,196,709
Beverage Container	Nov. 8th 1937	Jul. 15th 1941	2,249,051
Chemical Feeder	Oct. 2nd 1952	Oct. 23rd 1956	2,767,846

3. Project Presentation

The Buffalo Museum of Science has entrusted the Buffalo State Art Conservation Department with the restoration and preservation of an electric clock and globe created by the 'Universal Clock & Globe Corporation'. The object features a number of potentially complicated treatments that span a variety of materials. Characterizing the various materials also presents the opportunity to use analytical techniques and equipment currently available within the department.

3.1 Uniclok Condition Assessment

In its current state, the object is structurally, aesthetically and functionally compromised. The globe form supporting the paper gores is split, and as such the two hemispheres do not fit together correctly. The paper gores have an aged coating that has discolored considerably, and appears blotchy in places. Previous restoration attempts are evident in the selective rewiring of the internal components with newer plastic sheathed wires, and presence of heavily degraded pressure sensitive tapes applied to the paper gores around the equator. The tape is very discolored and brittle, and appears to have negatively impacted the surrounding paper support. Two calottes surrounding the North Pole are in an advanced state of polymer deterioration. The discs have discolored and become very deformed. The lower calotte has broken away from a geared mechanism at the top of the globe that controlled its rotation, thus the function of the disc is also impaired in its current state. In addition, pieces of the calottes have broken away and become fused to the paper gores. The electrical wiring is exposed in places and as such the piece cannot be safely connected to a power source to assess its functionality without some intervention.

The nitrocellulose globe material is extremely brittle. Both the upper and lower hemispheres are cracked. The crack in the upper hemisphere is 5 ½" in length and travels upwards from the equator through the central Pacific Ocean to the Aleutian Islands. The crack in the lower hemisphere is 5 ¾" in length and travels towards the pole in an arced fashion starting in western equatorial Africa. In both instances the brittle gores have tears corresponding to the crack.

The flange on the lower hemisphere displays extensive internal crazing corresponding to the adhesive line. This crazing also appears to continue through to the globe which may indicate that the adhesive used to join these two pieces has locally accelerated the aging of the plastic.

The cellulose acetate light shade, that was formerly responsible for indicating which portions of the globe were in darkness and which were in light, is severely degraded. The dark-brown, glassy and incredibly brittle form has shattered, fallen out of its mount next to the light bulb, and is now lying in the bottom of the globe accompanied by a greasy residue. Every part of the internal mechanism of the globe has a layer of white corrosion, likely caused in part by exposure to the off-gassing of acetic acid from the degraded cellulose acetate shade.

The paper gores are extremely brittle, especially around the equator of the lower hemisphere where the paper has a brown stain ~ ¾" wide. This staining corresponds to the adhesive join of the cellulose nitrate flange to the lower hemisphere substrate. The stain may have developed from the migration of the adhesive through the plastic, or it may have been caused by acidic off-gassing resulting from the localized degradation of the nitrocellulose substrate around the equator (noted above). There are numerous instance of localized tenting of the paper support on the globe surface. Pressure sensitive tape has been applied directly to the paper across the equator seam, presumably to hold the globe together. The tape has become brittle and discolored. There are localized losses to the paper gores especially around the equator, and the North Pole. The northern regions of the globe where the paper has come into contact with the deteriorated celluloid calottes is characterized by a ring of reticulated brown accretions.

Other than a layer of dust and dirt, the majority of the external metal structure is covered in a thick, dark-grey oxide, all of which gives the object an overall dull appearance. The hinge on the PL front face of the latitude indicator ring is broken and one whole side of the hinged joint is missing. This makes the globe and its supporting structure somewhat unstable when it is in its opened position. The calendar ring is slightly warped and there is an irregular shaped deposit of material on the top rear (PR) of the calendar ring.

The two cellulose acetate calottes at the North Pole are heavily degraded and deformed. The upper calotte (date dial) is delaminating and has numerous losses. The lower calotte (time dial) has broken away from a geared mechanism at the top of the globe that once controlled its rotation, thus impeding the functionality of the dial. As the polymer has degraded the lower calotte has become fused to the upper gores. A faint crack extends across the lower calotte, essentially splitting the disc in half. The calottes exhibit both an oily residue on their surfaces, and what appears to be a needle-like, crystalline solid.

The rubber sheath of the main power cord is split where it enters the metal body of the globe, and also where it enters the plug. The copper wires are exposed at the screw-connectors in the plug. If the plug once had a protective cap to shield the user from the internal wiring, it is now missing.

4. Objectives

As indicated by the condition assessment, the state of the object is somewhat dire. The curator at the Buffalo Museum of Science recognizes that some of the condition problems may be unsolvable, but is hopeful that the piece and some semblance of its unique functionality can be salvaged. The overall objectives for this project are:

- To use scientific analysis and scholarly research to identify the original materials and techniques used in the construction of the piece.
- To establish how the clock and globe mechanism works.
- To reduce the oxidative layer on the metal clock casing and reveal the original metal coating, or patina.
- To consolidate the cracks in the globe and safely provide a supportive lining for the globe to minimize damage as the globe material degrades.
- To return the clock and globe to a functional state, as much as safely possible, while maintaining the look and feel of the original mechanism and electrical wiring. This will also involve the refabricating of the degraded calottes.

5. Technical Breakdown of the Clock and Globe Mechanism

5.1 The Clock

Parts of the clock and globe train are indicated by capital letters that relate to Figure 12 through Figure 14. The heart and soul of the Uniclok is a Telechron Type-B2 synchronous motor. It provides enough torque to power all of the clock trains as well as those that control the rotation of the globe and the internal light shade/filter. The Type-B motor was patented by Henry Warren in 1922 (Warren, 1922).

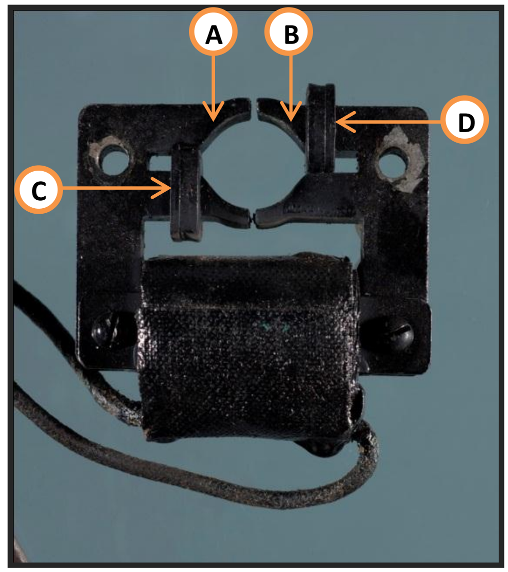


Figure 12: *Telechron Type B coil or 'stator' showing the poles of the magnet (A,B) and the shading coils (C,D).*

The motor is mounted to the rear of the brass base plate where it sits in a Telechron B coil or *stator*. The coil is an electromagnet whose poles (A,B) are positioned around the tail of the electric motor which houses a rotor. The stator also has two shading coils (C, D) which create a rotary magnetic field and power the motor's internal rotor by magnetic induction (Warren, 1918). With a 60 hertz alternating current power supply the rotor spins at ~3600 revolutions per minute (RPM) about a central shaft. A reduction train in the motor reduces the output to 1 RPM (Clockhistory.com, October 28th 2012).

The long, hollow output shaft (E) and pinion (F) from the electric motor are fitted through an aperture in the plate. The shaft and pinion rotate at one revolution per minute and acts as the central arbor for the dial train. The second hand (S) is press-fit into the motor's hollow shaft and thus rotates once every sixty seconds as expected. The 9 tooth pinion (F) on the output shaft (E) powers the entire dial train.

The first gear in the dial train is a 60 tooth wheel (G) co-axled with a 7 tooth pinion (H). The pinion drives the 63 tooth center wheel (I) and 14 tooth cannon pinion (J) which is centered on a hollow shaft (K) to which the minute hand (Q) is attached and which slides over the shaft from the motor. The minute hand is secured to the shaft using a knurled ring (R) which screws to threading on the center wheel shaft.

The hour train is powered by the cannon pinion (J) driving the 28 tooth minute wheel (L) which is co-axled with a 6 toothed pinion (M). This pinion in turn drives the 36 tooth hour wheel (N), which is attached to the overall mechanism via the hour pipe (O), a hollow shaft that slides over the concentric shafts of the motor and center wheel at the center of the plate. The hour hand (P) is pressure fit to the hour pipe.

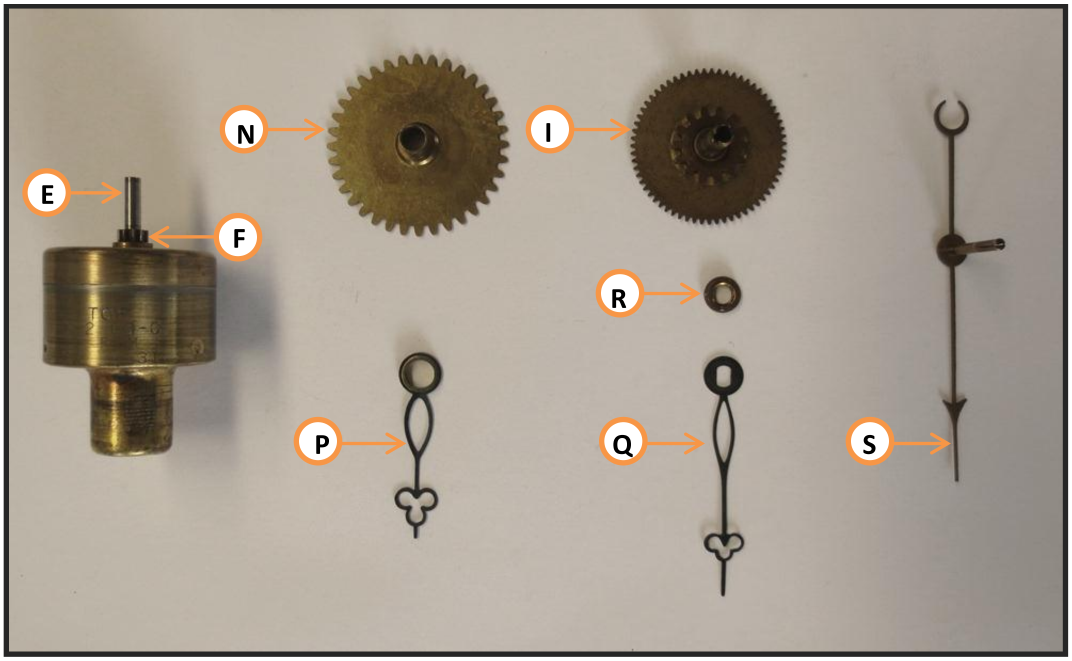


Figure 13: *Accessory image of clock parts. From left to right, a Telechron Type-B synchronous motor (E,F), the hour wheel (N), the hour hand (P), the center wheel (I), the knurled ring (R), the minute hand (Q) and the second hand (S).*

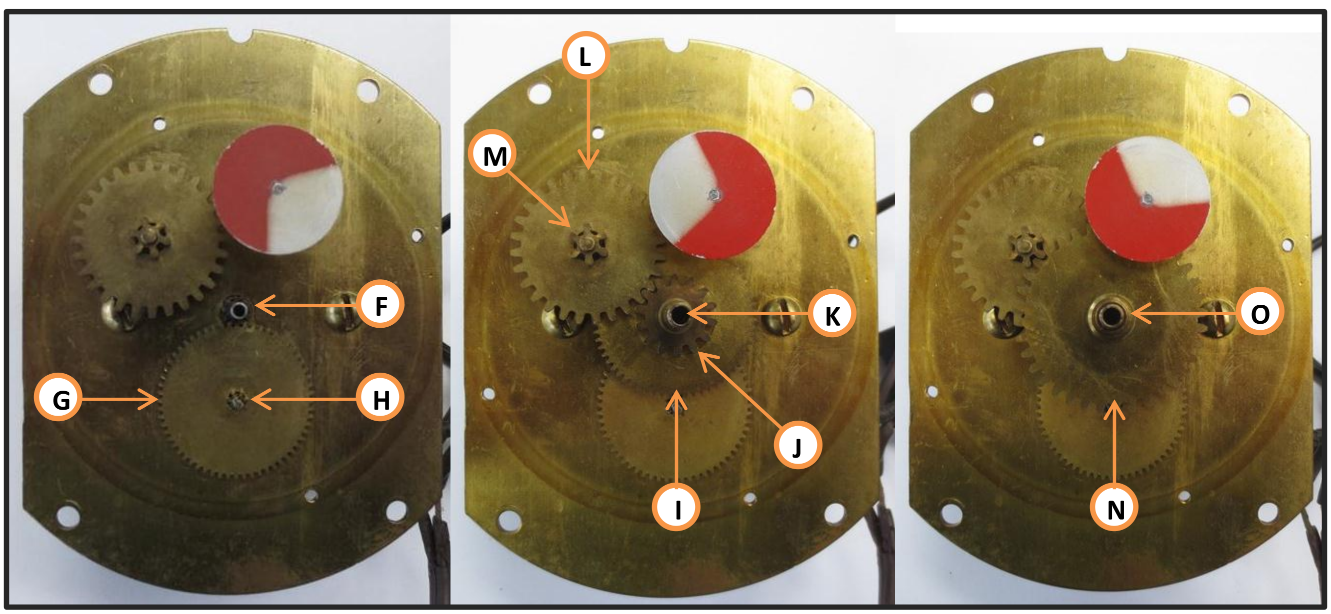


Figure 14: *Visual breakdown of the dial train clock components: The leftmost image shows the clock plate with the motor shaft (E) and pinion (F) inserted from the rear. The center image shows the dial train with the center wheel (I) and cannon pinion (J) installed over the motor shaft, driving the minute wheel (L,M). The rightmost image shows the hour wheel (N,O) installed over the shaft of the minute wheel.*

5.2 The Globe

The Uniclok globe mechanism is a complicated device containing two dial trains in addition to that of the clock. These trains are responsible for the automatic rotation of the globe, and the annual rotation of the light shade about the internal light source to indicate the shadow of the Earth in relation to the seasons.

The first globe train starts from an irreversible worm gear connected to an arbor extended through the rear of the main plate from the hour train. The worm gear (A) is the beginning of an overall reduction train that reduces the rate of rotation of the hour train by a factor of twenty-four such that the globe rotates on its axis one full revolution in a twenty-four hour period. The worm initiates this process by turning one full revolution every two hours. The worm meshes with a pinion (B) that drives a twelve to one reduction train comprised of two drive-shafts (C, D) positioned at ninety degrees to one another. The second shaft (D) in this assembly is the main axis of the lower hemisphere.

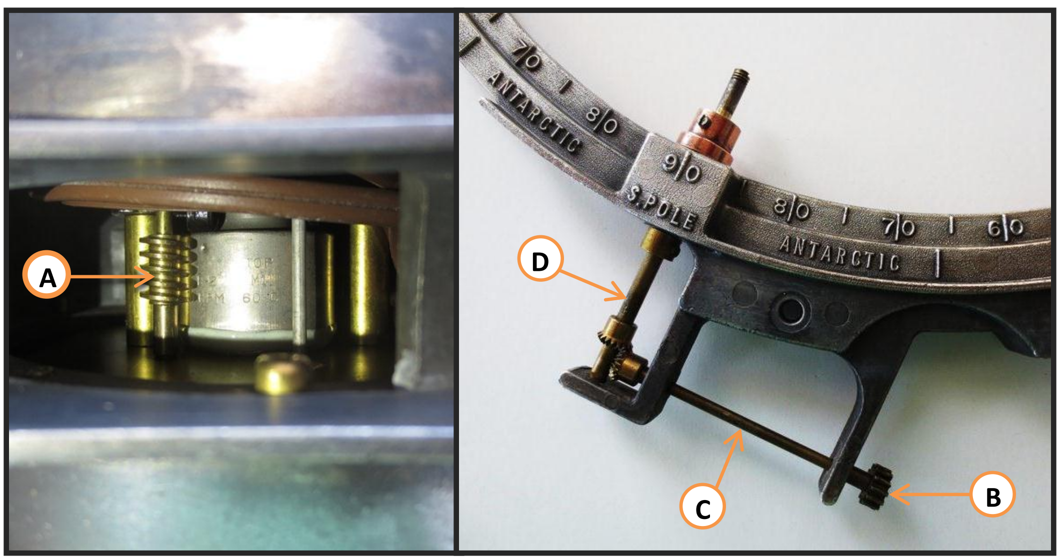


Figure 15: *The drive train that controls the rotation of the lower hemisphere with significant features labeled.*

The two halves of the globe are joined together by a flange on the inside rim of the equator. The tight pressure fit between the two hemispheres ensures that the lower half of the globe drives the upper portion. The motion of the lower hemisphere is transferred to a second gear train contained within the globe that automatically rotates the day/night discriminator 1/365 of a revolution every day. The hub (E) that connects the upper hemisphere to the upper frame supports a beveled frusto-conical gear (F). The gear train is centered about a cast zinc bracket that is used to hold many of the mechanical features in place. The aforementioned beveled gear (F) slides up and down on the hub's shaft on a key, relying on gravity to ensure a constant engagement with an identical beveled gear (G) set in a perpendicular orientation, thus bending the axis of rotation of the gear train by ninety degrees. Both beveled gears have the same number of teeth and thus revolve in concert with the globe at one revolution per day. The second beveled gear is co-axled with an eight toothed pinion (H). The pinion drives a seventy-three toothed wheel (I), which in turn drives a shaft supporting another irreversible worm-gear (J) at a rate of one revolution every nine days and three hours. The worm gear (J) is meshed with a forty tooth worm-wheel (K), that once again bends the axis of rotation ninety degrees and reduces the revolution rate to once per year (Schulse 1934)[8]. The worm-wheel is set on friction clutch that also supports a secondary wheel (L) that drives an intermediate idler (M) which in turn drives the gear mounted to the light shade support (N). This latter gear and the gear connected to the worm-wheel by the friction clutch both have twenty four teeth and thus provide no further reduction, transferring the rotation rate of one revolution per year to the light shade.

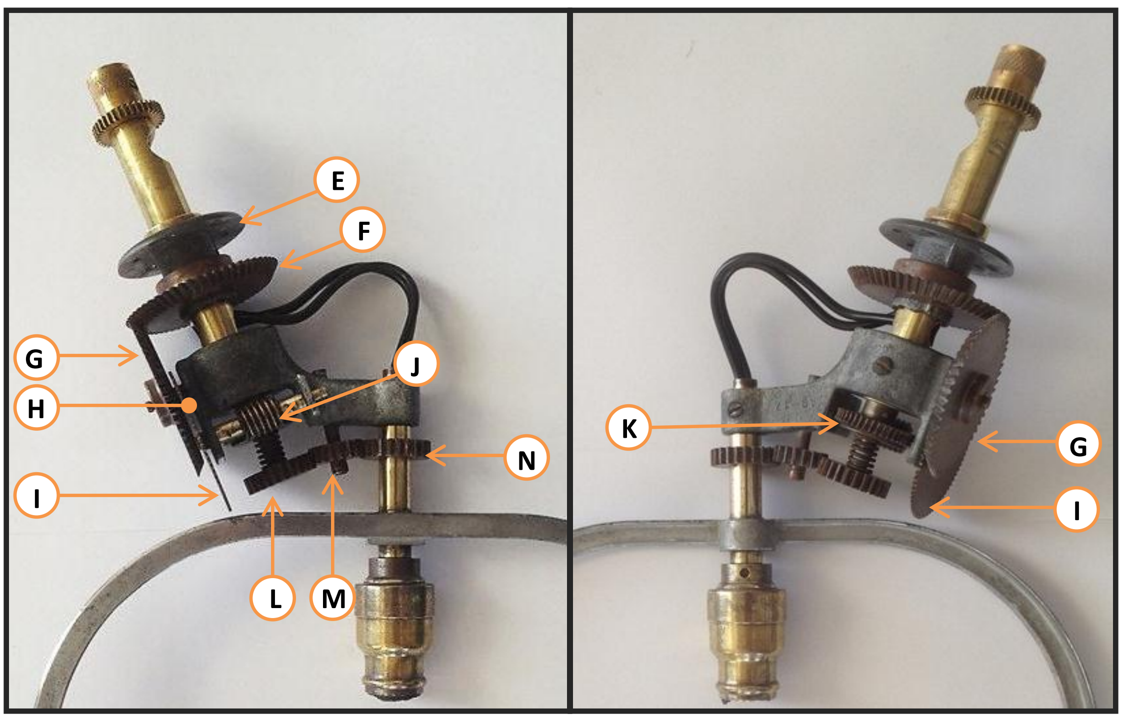


Figure 16: *The gear train for the internal mechanism driving the daylight/night discriminator, with significant features labeled.*

[8] Note: the gear ratios on the Uniclok reduction train differ from those outlined in the patent document (US1,959,601) (Schulse 1934) which reduced the rate of reduction with a six tooth pinion, followed by a seventy-three toothed wheel and a thirty toothed worm-wheel. The net reduction in revolution rate is however identical.

Two features critical to the success of the clock as a demonstration tool are the friction clutches located at the southern point of attachment, and in lower internal mechanism. Both clutches are essentially comprised of two metal discs set together with a compressed spring. They ensure that the motion of the clock and internal mechanisms can be the transmitted to subsequent sections of the gear train, while not allowing the manual rotation of the globe or the daylight/night discriminator to interfere with and damage the clock movement.

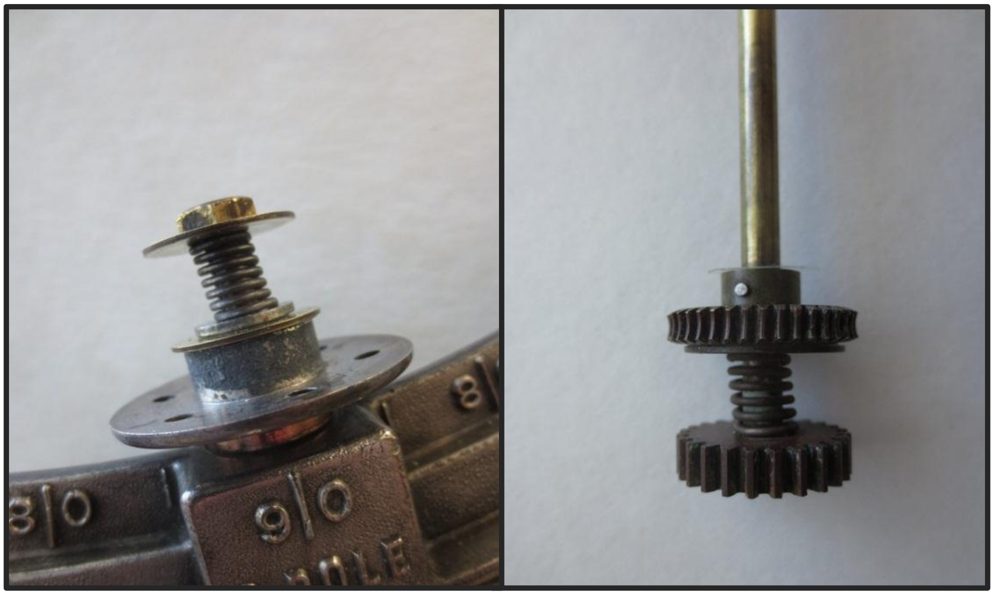


Figure 17: *The two friction clutches used in the globe gear train. The leftmost image is the clutch at the attachment point of the southern hemisphere, which enables the globe to be rotated in any direction without thwarting the clock movement. The image on the right is the clutch from the gear train for the daylight/night discriminator which allows the lightshade to be manually rotated without impacting the upstream components of the mechanism.*

6. Materials and Analysis

The Uniclok globe was analyzed in order to characterize its materials, which would in turn influence the most appropriate treatment for each of its constituent components. The clock and globe instrument is a composite object made up of various metal alloys, polymeric materials, paper gores and coatings. Each of these required different handling and treatment regimes, which needed to be compatible with surrounding materials. For example, it would not have been appropriate to remove a coating from the paper gores using a polar solvent without knowing what effect this would have on the underlying plastic substrate. A combination of analytical techniques was performed on the Uniclok to identify organic and inorganic compounds in the materials including microchemical testing, Fourier Transform Infrared (FTIR) spectroscopy, Gas Chromatograpy - Mass Spectrometry (GC-MS), and X-ray Fluorescence (XRF) spectroscopy.

6.1 Methods of Analysis and Instrumentation

Microchemical spot testing is a cost effective method to assist in the identification of an unknown material, and is an excellent complement to more sophisticated analytical techniques. Many of the published spot tests can be completed with chemicals and equipment commonly found in a scientific laboratory. Two test methods were selected from *Material Characterization Tests for Objects of Art and Archaeology* (Odegaard et al., 2000) to attempt to identify the material used to make the globe calottes. Given the age of the piece it was likely that the unknown plastic was cellulose based, so the first test looked for the presence of cellulose. This test was combined with another that specifically looked for the presence of cellulose nitrate.

Fourier Transform Infrared Spectroscopy uses infrared radiation to excite organic molecules in order to produce translational, rotational and vibrational motion. The energy required to excite the molecule and produce these movements are characteristic of specific functional groups within the molecule's atomic structure. The measurement and interpretation of characteristic energy and motion signatures is realized in a spectrum. The spectrum can then be used to determine the identity of an unknown material through analysis of the characteristic peaks present in a sample, and is aided by comparison with published library spectra of specific known compounds. FTIR analysis is generally thought of as being destructive or micro-destructive, especially where techniques that require sampling and/or the use a compression diamond cell are involved. The use of an Attenuated Total

Reflectance (ATR) accessory can provide non-destructive infrared spectroscopic analysis of an object depending on its size and fragility, ie: a relatively dense object that is hearty enough to manipulated and pressed with some force against the diamond ATR crystal while the analysis is completed.

Pyrolysis Gas Chromatography – Mass Spectrometry (Py-GC-MS) is an analytical technique ideally suited to the identification of individual components in complex mixtures. In this study it was specifically employed to identify the plasticizers used in the production of the globe material. Py-GC-MS is a three-part process. Firstly, the sample is rapidly heated in the absence of oxygen (pyrolyzed) such that the material is simultaneously depolymerized and volatilized. For some polymeric materials derivatizing agents, like tetramethyl ammonium hydroxide, are often mixed with the sample to increase their volatility, though no such agent was used in this study. The sample is then injected into the gas chromatograph, where the different component materials are mixed with a gas carrier (Helium in this instance). The sample mixture enters a heated column packed with a modified siloxane polymer and depending on the various component materials' polarities, sizes and relative affinities for the stationary and mobile phases they will elute through the column at different rates. After the components are separated by GC, they are detected and analyzed by the mass spectrometer. The MS used in this study converts the gaseous molecules from the GC outlet to molecular ions (positively charged radical cations). The ions are directed through a quadrupole mass filter to enable the identification of ions with differing mass to charge (m/z) ratios, before being passed to the detector, which produces the mass spectrum for each molecule it encounters. Due to the nature of the process GC-MS is a destructive analytical technique.

X-ray Fluorescence spectroscopy is a non-destructive analytical technique used primarily to characterize inorganic materials. When a material is exposed to high energy X-rays, atoms within the material become excited and eject one or more electrons from their inner orbitals. In turn, electrons in higher energy orbitals cascade to fill the vacancy in the lower orbital. This process emits fluorescent radiation having an energy signature that is characteristic of the atoms present in the sample material. The intensity of these radiation signatures are measured by a detector in the XRF device and a spectrum is produced that can be visually analyzed.

The metal and glass components of the globe were analyzed *in situ* with XRF. The organic polymeric materials in the globe were analyzed with microchemical testing and

FTIR. In context with this object, given its size and fragility, these types of analysis were both destructive and small samples were taken from each of the areas in question. For the internal lightshade and the calottes this presented no ethical issue given that the plastics were degraded beyond the point of stabilization, and were either (in the case of the calottes) actively delaminating/spalling, or (in the case of the lightshade) shattered and reduced to extremely small fragments.

6.2 Analysis of the Uniclok's Polymeric Materials

The identity of the material comprising the degraded calottes, the severely deteriorated internal light shade and the brittle globe substrate was determined using microchemical testing and attenuated total reflection (iTR ATR) FTIR spectroscopy on a Nicolet 6700 FTIR spectrometer (Thermo Scientific) with a Thermo Scientific Smart iTR ATR accessory.

The micro-chemical test for cellulose, using aniline acetate and pyrolysis, returned a positive result for all of the polymeric materials. Further to this the globe substrate returned a positive result for cellulose nitrate in that the aniline acetate indicator turned a yellow color. This was confirmed using the microchemical test for cellulose nitrate (CN) using a diphenylamine indicator, where only the globe polymer returned a positive result. Neither the calottes nor the internal light shade tested positive for CN. Overall this indicated that all of the plastics in the object were cellulosic in nature, but only the globe was made from cellulose nitrate.

FTIR analysis using the attenuated total reflectance accessory confirmed that the calottes were made from cellulose acetate. Initially the only samples available for testing were the highly degraded, exposed portions of the calotte material and areas where the degradation products had been wiped away. The ATR output for the heavily deteriorated surfaces indicated the presence of triphenyl phosphate (TPP) (see Figure 18). TPP is the (tri)ester of phosphoric acid and phenol, and was commonly used as a plasticizer and flame retardant in cellulose acetate (Shashoua 2008). The presence of white needle-like crystals on the surface of the calottes was consistent with chemical manufacturers' descriptions of their raw TPP product. However, the presence of triphenyl phosphate was not diagnostic in and of itself given that in was also used as a plasticizer in other cellulose based polymers, most notably cellulose nitrate from the mid to late 1930s (Shashoua 2008, 177).

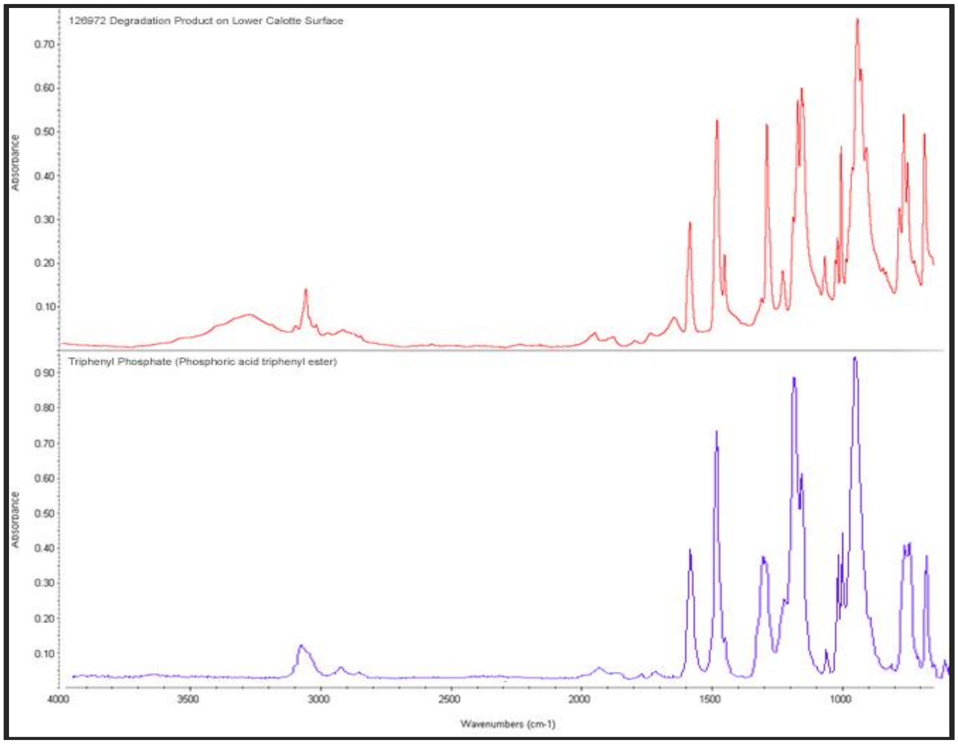


Figure 18: *A comparison of the FTIR spectra for a sample of the degradation product taken from the surface of the lower calotte (upper spectrum), and a library reference spectrum for triphenyl phosphate (adapted from FTIR transmittance spectrum on NIST Chemical Webbook).*

The cleaned surfaces of the degraded calotte samples produced a spectrum (see Figure 19) that had strong similarities with that of cellophane, a regenerated cellulose product. A recent study in to the degradation of cellulose acetate museum artifacts showed that deacetylation is the primary cause of deterioration (Littlejohn et al. 2012), and this is reflected in the comparison of a library reference spectrum for cellulose acetate with the spectrum of the polymer sample taken from a clean portion of the calotte (see Figure 20). The loss of acetate groups in the degradation process is reflected in a reduction of the carbonyl peak and growth in the hydroxyl peak as the polymer reverts back to cellulose (Littlejohn et al. 2012). The reference spectrum showed strong carbonyl peaks (~1700 cm^{-1}), representing the presence of acetyl groups, but weak hydroxyl peaks at ~3400 cm^{-1}. Conversely, the degraded calotte polymer showed strong, broad hydroxyl peaks at 3362.52 cm^{-1}, and no characteristically strong carbonyl peak. Again, these observations were not entirely conclusive for the identity of the polymer given that the cellulosic reversion process is not unique to cellulose acetate. Denitration of nitrocellulose could conceivably produce a similar spectrum.

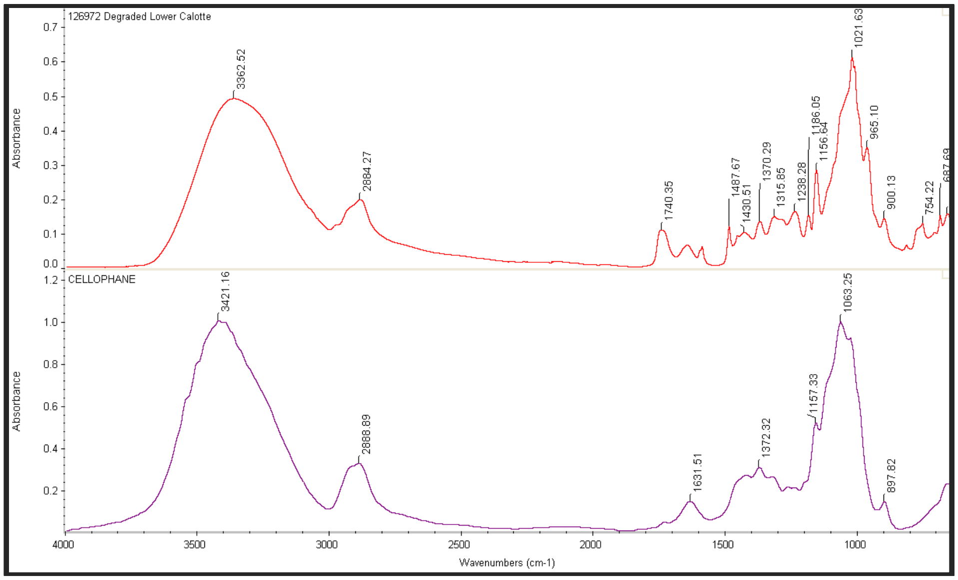


Figure 19: *A comparison of the FTIR spectra for the polymer sample taken from the lower calotte, and a library reference spectrum for cellophane (Hummel Polymer Sample Library: index 40). The spectra showed a 60.79% match.*

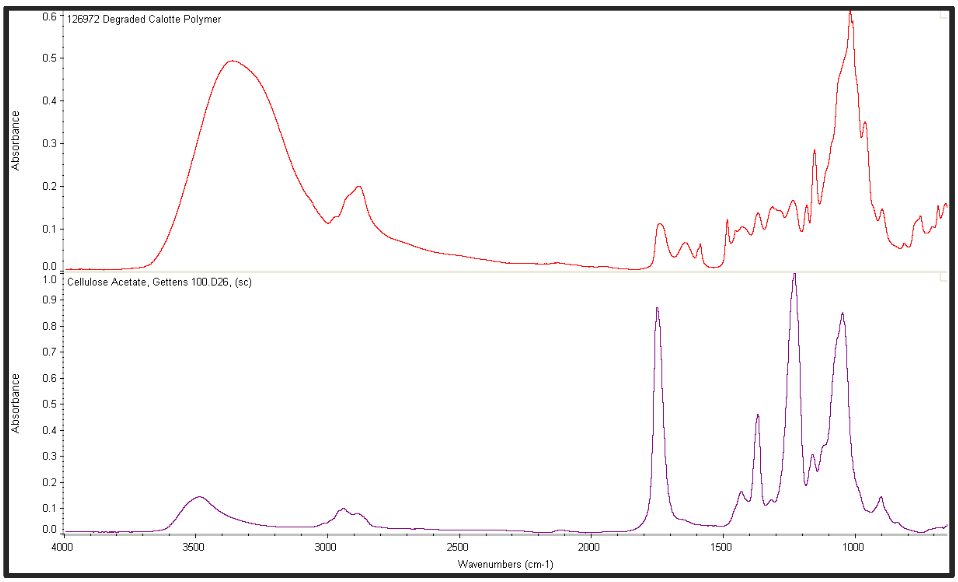


Figure 20: *FTIR spectra comparing the cleaned portion of the lower calotte material (upper spectrum) to a library reference for cellulose acetate.*

Clear evidence that the mystery polymer was indeed cellulose acetate was gleaned from calotte samples that were exposed as the globe mechanism was slowly disassembled. A portion of the upper calotte hidden beneath the metal frame showed very little in the way of degradation; the substrate was structurally sound and barely discolored. The spectrum for this sample showed a 69.99% match with library spectra of cellulose acetate (see Figure 21), and showed no characteristic nitro peaks at ~1278 cm^{-1} and ~1634 cm^{-1}, thus confirming that the unknown cellulosic polymer was indeed cellulose acetate.

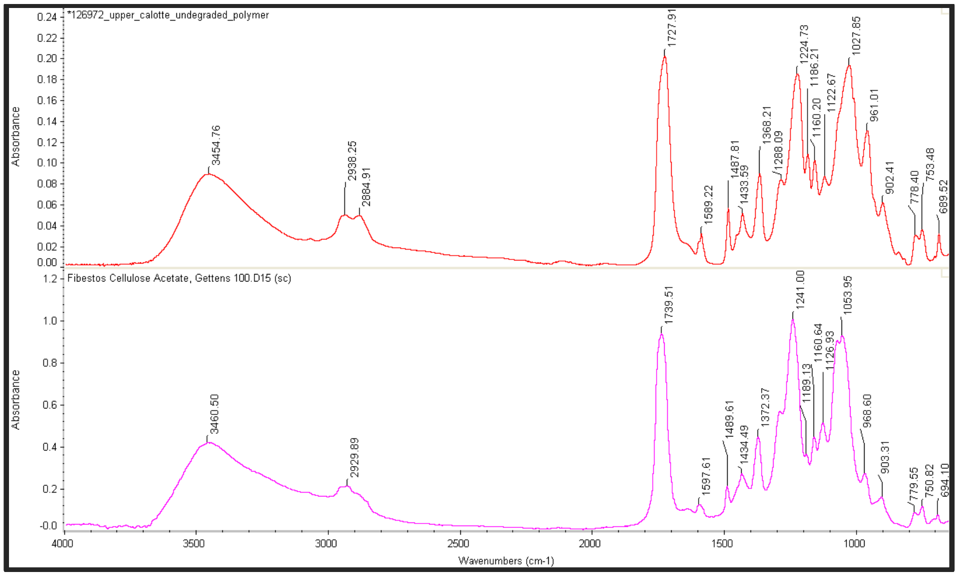


Figure 21: *A comparison of the FTIR spectrum for the polymer sample taken from the upper calotte (Sample Reference: 1213334), with library reference spectra for Fibestos Cellulose Acetate (Gettens Collection: index 261). The spectra showed a 69.99% match.*

The severely degraded light shade, shared the same characteristic markers as the calottes. Once again the presence of triphenyl phosphate was detected by ATR on the severely degraded outer surface. The protected inner surface of the lightshade produced a spectrum that shared strong similarities with regenerated cellulose (see Figure 22), and thus was identical in character to the spectra produced from the analysis of the calottes. There is a very small carbonyl peak shown in the spectrum, but the hydroxyl peak is especially pronounced.

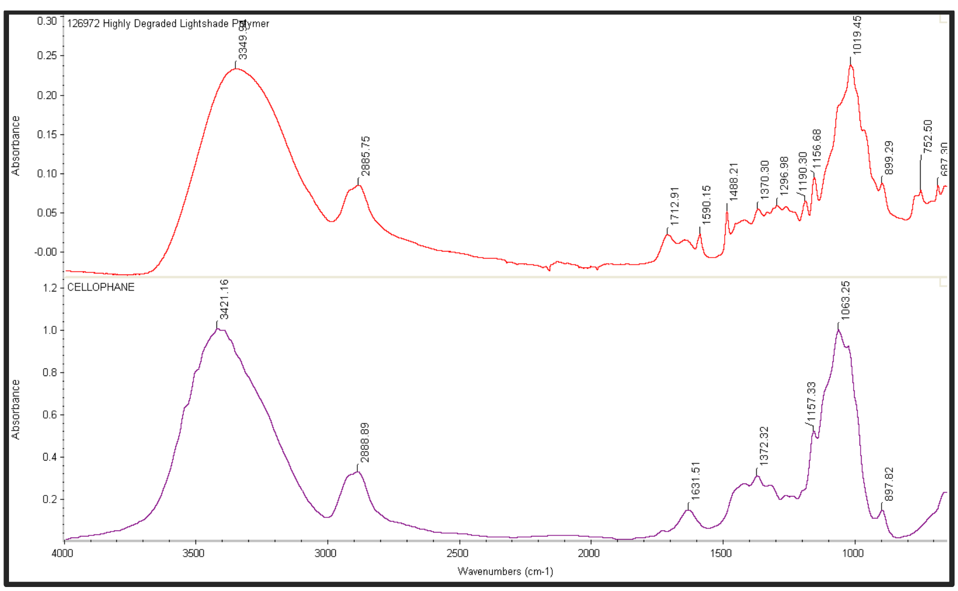


Figure 22: *FTIR spectra comparing the inner substrate of the lightshade material (upper spectrum) to a library reference for cellophane (Hummel Polymer Sample Library: index 40). The spectra showed a 64.54% match.*

The spectrum of the unknown polymer comprising the globe hemispheres confirmed the conclusion indicated by the microchemical testing – that the polymer was cellulose nitrate. The library spectrum for an aged sample of cellulose nitrate (IRUG Synthetic Resins: index 65) matched the spectrum of the globe material with 71.85% certainty (see Figure 23). Visual analysis of the spectrum for the globe polymer also strongly indicates that the material is cellulose nitrate. The strong sharp peaks at 1274.20 cm^{-1} and 1632.95 cm^{-1} are characteristic for nitro functional groups (Shashoua 2008, 257).

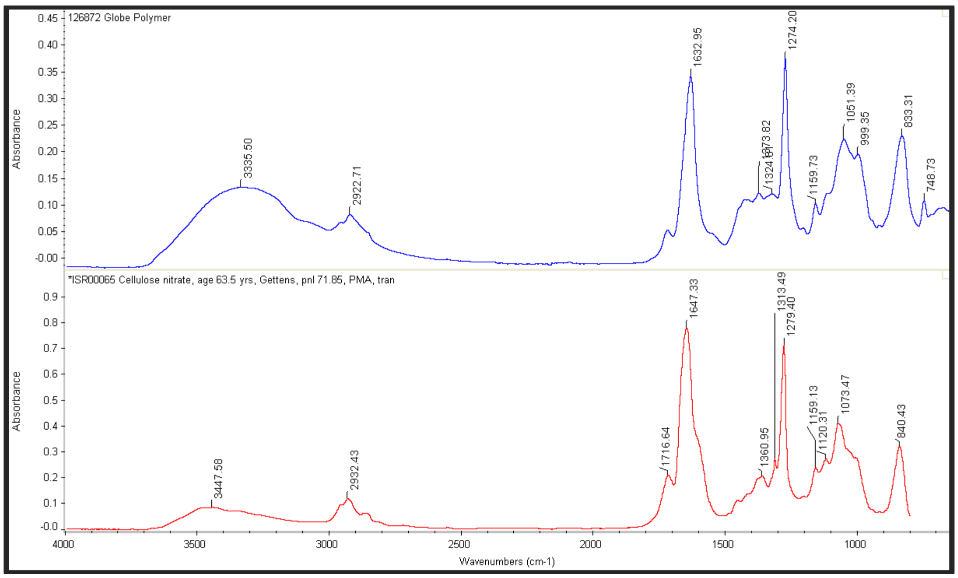


Figure 23: *FTIR spectra comparing the globe material (top) to a library reference for cellulose nitrate aged 63.5 years (IRUG Synthetic Resins: index 65).*

6.3 Analysis of the Globe Plasticizers

Py-GC-MS was used to identify the two major plasticizers in a sample of the cellulose nitrate globe. When compared to NIST library reference spectra the two major peaks in the pyrogram for the CN sample (see Figure 24) at 7.251-7.444 minutes and 9.491 minutes were identified as camphor and dimethyl phthalate respectively. This finding is consistent with the literature which shows that camphor was used as a plasticizer for CN from 1870 and that phthalates were introduced in the early 1930s (Shashoua 2008).

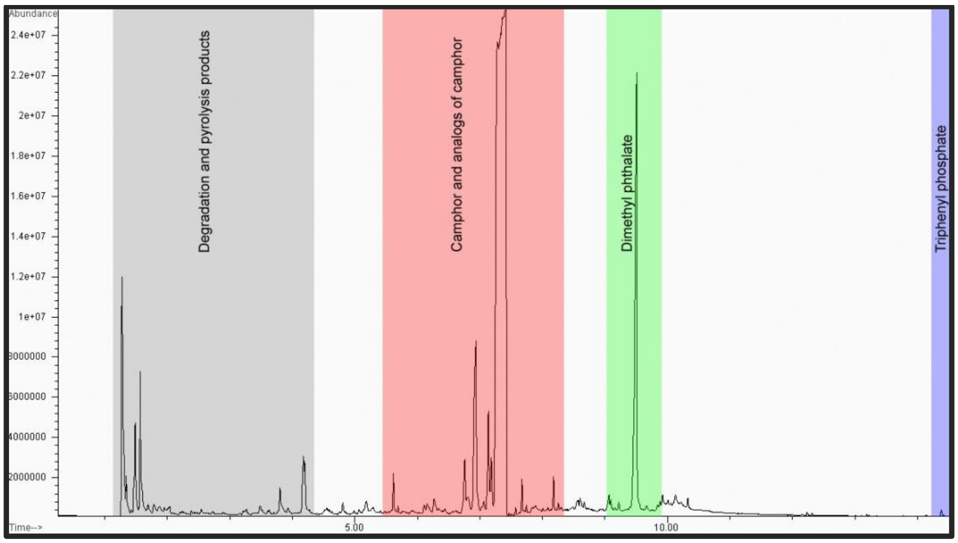
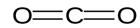
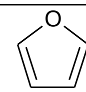
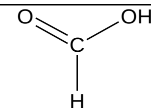
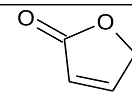
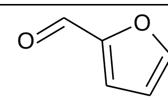
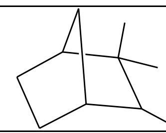
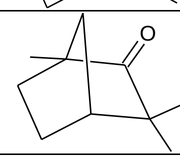
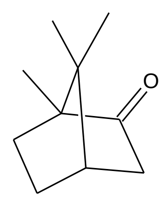
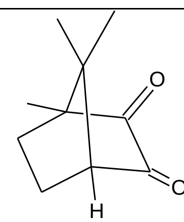
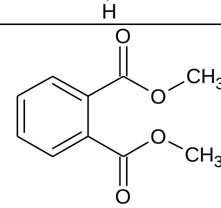
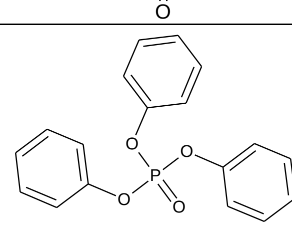


Figure 24: *TIC (pyrogram) for a sample of the globe substrate, showing the time intervals at which the various constituents eluted from the gas column. Significant peaks and groups of peaks are highlighted and labeled. Camphor is shown in pink, dimethyl phthalate in green and triphenyl phosphate in blue.*

Both the major and minor constituents that appear in the pyrogram (figure 24) above are outlined in Table 2. The minor compounds eluted in the first four minutes appear to degradation products (carbon dioxide and formic acid) and pyrolysis products in the form of analogs of furan. The range 5.610 minutes to 8.178 are all related to camphor enantiomers or analogs of camphor (e.g. isocamphane) the latter of which could be degradation products or impurities in the original camphor source. The strong sharp peak for dimethyl phthalate appears at 9.491 minutes. The appearance of triphenyl phosphate at 14.383 minutes could be misleading. While TPP was used as a plasticizer for cellulose nitrate from the 1940s (Shashoua 2008), the source of this peak in the sample (which came from the upper portion of the globe) is likely transference from the degraded cellulose acetate calotte that was in direct contact with the globe when the object was received from the Buffalo Museum of Science. The relative weakness of the TPP peak compared to the peaks attributed to camphor and dimethyl phthalate also suggests that it was not introduced specifically as a plasticizer.

Table 2: *Identification of the compounds comprising the major and minor peaks shown on the pyrogram for a sample of nitrocellulose taken from the Uniclok globe material.*

Time (minutes)	Compound Name	Peak Intensity	Diagram
1.285	Carbon dioxide	Minor	
1.484	Furan	Minor	
1.576	Formic acid	Minor	
3.801	2(5H) Furanone	Minor	
4.187	Furfural	Minor	
5.610	Isocamphane	Minor	
6.762	Fenchone	Minor	
6.929	Camphor	Minor	
7.135	Camphor	Minor	
7.251-7.444	Camphor	Major	
7.676	Camphor	Minor	
8.178	Bornanedione	Minor	
9.491	Dimethyl phthalate	Major	
14.383	Triphenyl phosphate	Minor	

6.4 Analysis of the Uniclok's Inorganic Materials

The Uniclok's metal base was heavily oxidized, and the clock casing and calendar ring had localized areas of wear intermitted with bright spots that had a nickel-colored luster. It initially appeared that the object had formerly been plated, and that the metal coating had subsequently eroded due to age, handling or overzealous polishing. X-ray Fluorescence spectroscopy assisted in the identification of the composition of the base metal alloy, the various decorative coatings, and the composition of the clock crystal.

Table 3: *Results of the X-ray Fluorescence spectroscopic analysis of the Uniclok's structural body. 'M' indicates a major constituent, 'm' a minor constituent and 't' indicates a trace element.*

Sample Site/ Number	S	Ca	Ti	Mn	Fe	Ni	Cu	Zn	As	Sr	Ag
Calendar Ring: Shiny region (1213288)	t	-	-	-	t	t	m	M	-	-	t
Calendar Ring: Oxidized region (1213283)	-	t	-	-	t	t	m	M	-	-	t
Calendar Ring: Oxidized region (1213677)	-	t	t	-	t	t	M	M	-	-	t
Calendar Ring: Cleaned region (1213678)	-	-	-	-	t	t	M	M	-	-	t
Clock Case: Worn Region of Rear Plate (1213681)	-	-	-	t	t	t	m	M	-	-	t
Clock Case: Worn Region of Rear Plate (1213683)	-	-	-	-	t	t	m	M	-	-	t
Clock Case: Plated/ coated region of Rear Plate (1213682)	-	-	-	-	t	t	m	M	-	-	t
Clock Case: Worn region on top of main body (1213691)	t	-	-	-	t	t	m	M	-	-	t
Clock Case: Coated (nickel-colored) region on top of main body (1213692)	t	-	-	-	t	t	m	M	-	-	t
Clock Case: Coated (nickel-colored) region on wing of main body (1213690)	t	-	-	-	t	t	m	M	-	-	t
Clock Base: Silvered portion (1213541)	-	-	-	-	t	t	m	M	-	-	t
Clock Base: Exposed copper portion (1213542)	-	-	-	-	t	t	m	M	-	-	t
Clock Base: Exposed copper portion (1213543)	-	-	-	-	t	t	m	M	-	-	t
Calendar Ring Deposit (1213676)	-	M	t	t	M	t	t	t	t	m	-

Table 3 shows the results of the XRF analyses of the metal alloy used to make the clock casing and globe frame. In all samples analyzed for the clock casing, clock base and the calendar ring, the major constituent of the metal alloy was zinc, with a consistently small percentage of copper and a trace of nickel and silver. Although XRF is not strictly a quantitative technique it is possible to compare relative readings of different elements captured using the same instrumental settings (voltage, current and live time) and hardware (tube, collimaters and filters). This is somewhat more valid when comparing two elements that have similar molecular weights, like copper and zinc (Dr. Aaron Shugar, 2013, pers comm), which, conveniently, were the major components of the alloy in question.

Table 4: *Averaged relative percentage composition of zinc and copper in each of the Uniclok's cast elements. These figures only relate to the zinc and copper Kα peaks and do not reflect the overall composition of the alloy which included traces of silver and nickel.*

Clock Case Component	Average Percentage of Zinc	Average Percentage of Copper
Calendar Ring	63.0%	37.0%
Clock Casing	85.2%	14.8%
Clock Base	77.8%	22.2%

The relative percentage composition with regard to the zinc and copper components of each of the castings is shown in Table 4. These figures indicate that although the alloy used in the Uniclok contained both copper and zinc it was not a typical yellow or red brass. These common brasses typically have a much lower percentage of zinc; yellow brasses have between 25% and 33% zinc, while red brasses contain approximately 15% zinc (Onlinemetals.com 2013). Given that the casing and frame were die-cast in the late 1920s or early 1930s it is very likely that a zinc-based casting alloy was used. Zinc-based alloys were commonly used to die-cast wares throughout the early twentieth century. They are ideal for this purpose given that they are inexpensive alloys that tend to have a low melting point and are easily handled due to their being less susceptible to gas absorption (Smith 1957). Zinc casting alloys are also relatively easy to plate and coat for protective and decorative purposes (Zinc Development Association 1975). Advances in the ability to purify zinc in the 1920s led to the development of relatively stable zinc alloys, most prominently the Zamak series in 1929. Although this would have coincided with the casting of the Uniclok globe, the XRF confirms that it was not cast from Zamak alloys, which were standardized in terms of composition and had a consistent 4% aluminum content. Aluminum was not observed in any of the spectra.

The unknown zinc alloys used in the casting of this object could be a series of proprietary mixes developed by the caster, who may have added copper to their zinc mixture to increase the alloy's corrosion resistance, strength and hardness (Smith 1957).

The noticeable variation in the zinc to copper ratios in each of the separate casting pieces comprising the Uniclok case and frame, and within some of the castings themselves, could be attributed to a localized surface enrichment of zinc caused by inverse segregation. This phenomenon can be caused through the rapid cooling of a metal alloy where the component with the lower melting temperature (in this case zinc) migrates to the surface by capillary action through the dendritic structure of the solidified copper-rich portions of the alloy (Habashi, 2008). In a die-casting workshop, where these clock cases were being mass-produced, it is reasonable to assume that a quick-turnover between castings would have been preferred, and that rapid cooling could have been a common practice.

The calendar ring and clock casing appeared to have, or have had, a silver coating. XRF showed clear attenuation in silver peaks for worn regions of the object compared to those that had intact shiny surfaces, as shown for the calendar ring in Figure 25.

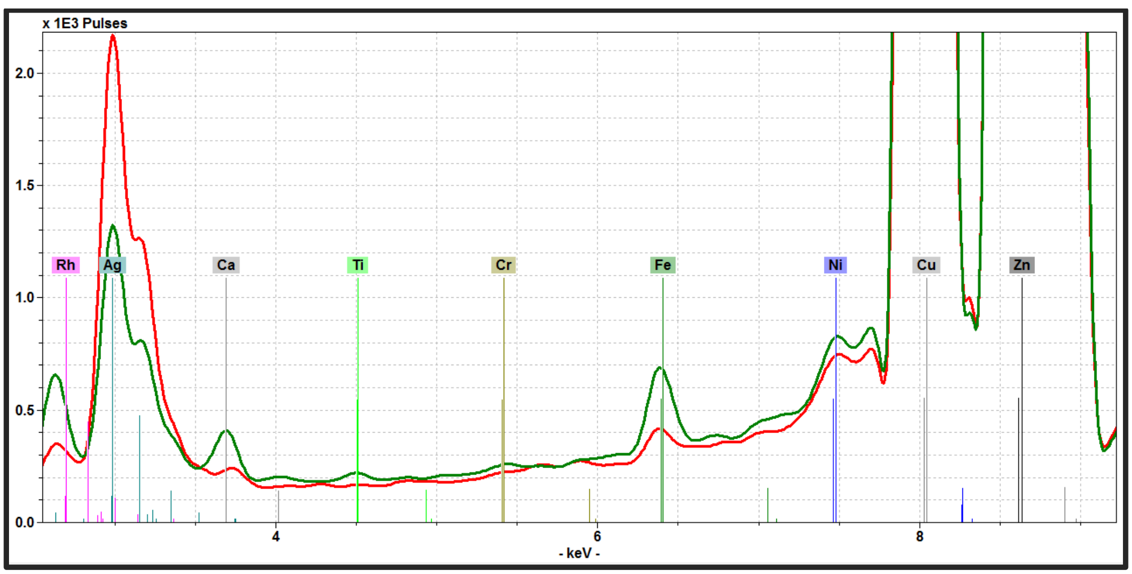


Figure 25: *XRF spectra for a worn region of the calendar ring (sample 1213289 – green spectrum) and an area that had an intact shiny luster (sample 1213288 – red spectrum). The attenuation of the green spectrum at 2.983 keV indicates a diminished presence of silver in the worn region. (Note: spectra were normalized off their Rhodium Kα peaks at~20.2 keV)*

Silver plating was visually most evident in the base of the clock. After the thick layer of corrosion was removed to reveal the surface of the object one could very clearly discern regions with a strong silvery luster from areas of copper and dull grey zinc, likely exposed from repeated campaigns of overzealous polishing. The XRF spectra back up this observation by showing attenuated silver peaks for the worn areas (see Figure 26).

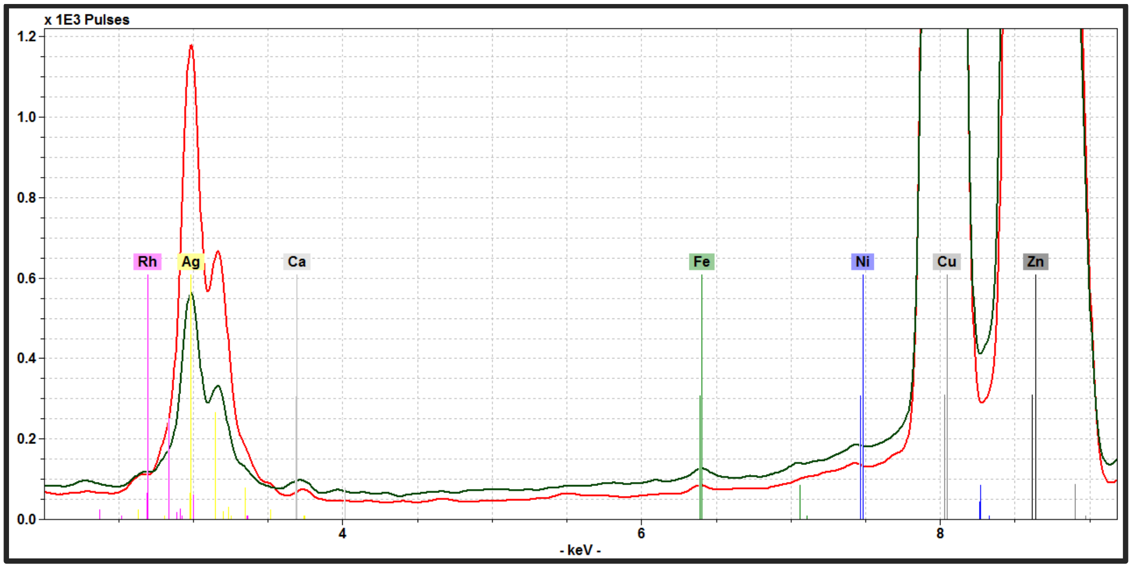


Figure 26: *XRF spectra for a region of the clock base that had an exposed copper surface (1213542 green) compared to an area that had an intact silvery lustre (1213541 red). The attenuation of the green spectrum at 2.983 keV indicates a diminished presence of silver in the worn region. (Note: spectra were normalized off their Rhodium Kα peaks at~20.2 keV)*

What initially appeared to be plated nickel surfaces on the Uniclok wings and clock body were most likely a tinted organic lacquer applied to the polished silver-plated zinc alloy. When comparing XRF spectra for nickel colored regions of the clock casing with those of adjacent regions of the exposed base metal there were no notable differences in composition.

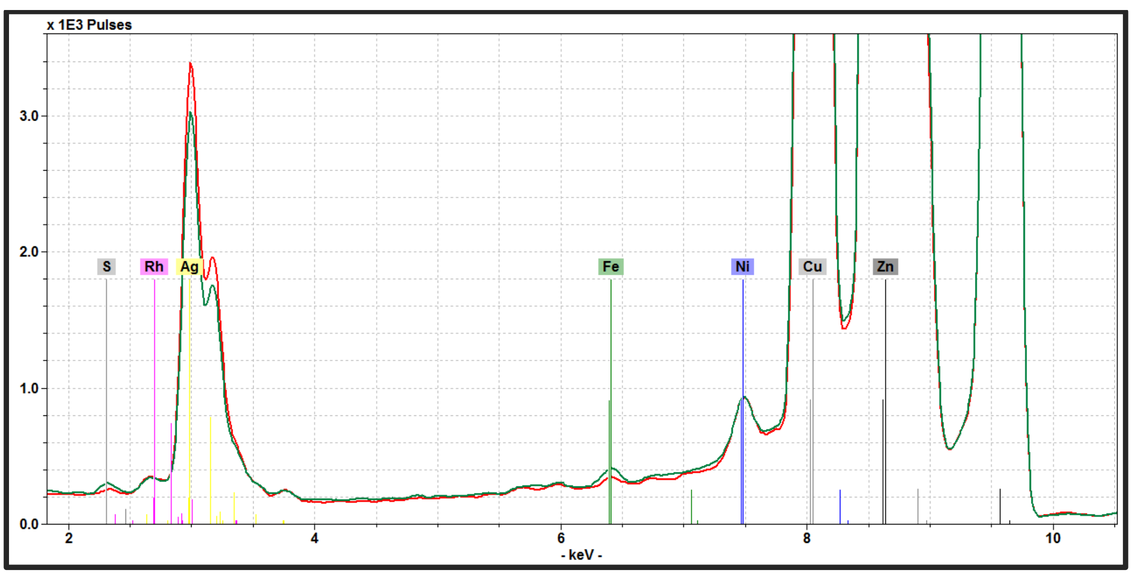


Figure 27: *XRF spectra for the main clock body (wings) comparing a worn region of exposed base metal (sample 1213691 - red spectrum) to a nickel colored area on the wing (sample 1213692 - green spectrum). There is no attenuation of the nickel peak at ~7.4 keV. Interestingly, L lines for silver appear to be more intense in the region of dull exposed metal. (Note: spectra were normalized off their Rhodium Kα peaks at~20.2 keV)*

Had there been a nickel layer deposited on the zinc alloy by some sort of electro-deposition method, one would expect a noticeable increase in the nickel peak at 7.4 keV for the green spectrum in figure 27. This was simply not the case. This finding fortuitously coincided with the discovery of a Uniclok floor model on eBay in excellent condition. The photos posted on the website showed a metal casing decorated with a shiny faux-metallic finish with a coloring that can only be described as 'unnatural' (see Figure 28) and very likely the result of a colored coating. Assuming that the advertised piece was in near original condition the presence of a colored lacquer would neatly explain why the XRF data did not distinguish between the nickel colored regions and the base metal.

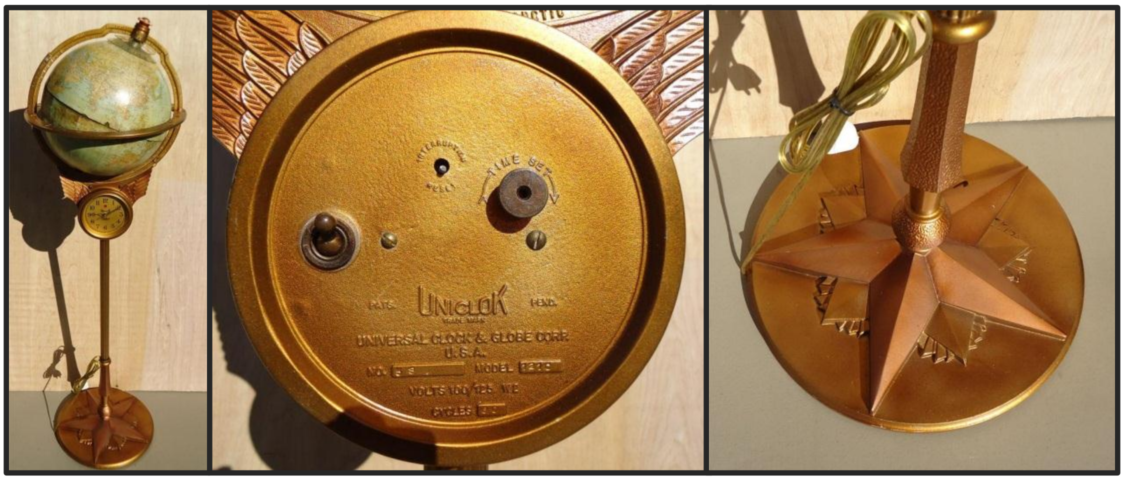


Figure 28: *Images of a Uniclok Floor Model 121C found on eBay. Note the bright coloration of the die-cast clock casing and stand elements.*

XRF analysis revealed that the deposit on the calendar ring, which initially appeared to be a casting flaw given that it had a patina identical in color to the surrounding metal, did in fact have a distinctive chemical composition. The strong Kα peaks for iron and calcium indicated that the deposit was not made from the same material as the die-cast clock case. This finding enabled it to be successfully removed from the calendar ring by simple mechanical cleaning.

Table 5: *Results of the X-ray Fluorescence spectroscopic analysis of the Uniclok's bezel and clock glass. 'M' indicates a major constituent, 'm' a minor constituent and 't' indicates a trace element.*

Sample Site/ Number	Si	Ca	Cr	Fe	Cu	Zn	As	Sr
Clock Bezel: Front (1213680)	-	-	m	-	t	M	-	-
Clock Bezel: Rear (1213679)	-	-	m	t	t	M	-	-
Clock Crystal (1213282, 1213283)	M	M	-	t	-	-	m	M

The clock bezel is a cast zinc-based alloy that has been chrome plated. All samples taken from the bezel (see Table 5) showed consistent major peaks for zinc and trace peaks for copper indicating that the alloy composition was weighted heavily in favor of zinc (approximately 97%). Both spectra showed a consistent minor peak for chromium. The sample taken from the rear of the bezel showed a comparatively attenuated peak which is consistent with the fact that the rear surface did not exhibit the distinctive chrome coating (see Figure 29). The trace of iron was likely attributed to dirt, though contamination of casting alloys with ferrous content was not uncommon.

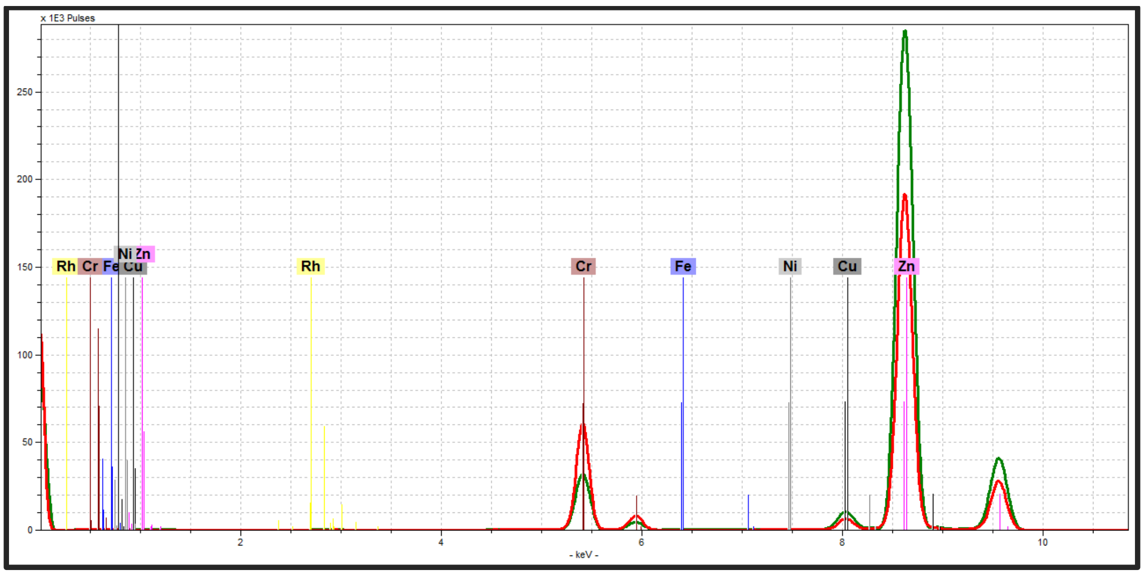


Figure 29: *XRF spectra comparing the front of the chrome plated bezel (sample reference 1213680 in red) to the rear of the bezel (sample reference 1213679 in green). The attenuation of the chromium peak in the spectra taken from the rear of the verso coupled by the increased intensity of the zinc Kα peak indicates that the piece is chrome plated on the front of the casting. Spectrometer was operated at 40 kV and 1000 µA. (Note: spectra were normalized off their Rhodium Kα peaks at~20.2 keV)*

The spectra for the Uniclok clock glass show major peaks for silicon, calcium and strontium, with a minor peak for arsenic and a trace of iron. The presence of silicon, calcium and strontium are expected given their common usage in modern glass production. The traces of iron could be attributed to either dirt deposits on the surface of the glass, or a contaminant in the glass batch. The presence of arsenic is consistent with commercially produced glass in the early-mid twentieth century. Until recently, arsenic oxides were commonly used as fining agents, which served to remove or reduce gas bubbles (also referred to as 'seed') from glass batches (Shelby 2005).

7. Treatment

7.1 Disassembly and Cleaning of the Clock Mechanism

The clock was disassembled using Herman E. Schulse's Uniclok Handbook, information contained within his patent for the globe mechanism, suggestions gleaned from online Telechron collectors' forums and X-radiographs of the front and side of the object.

To access the rear of the clock the back plate had to be detached by removing two screws, the knurled ring around the power switch and unscrewing the time adjust knob by turning it in an anti-clockwise direction. The plate was press fit on to the main clock casing. Years of corrosion had ensured that this fit was quite tight, and the plate was unable to be moved with finger pressure. It was eventually able to be removed by gently tapping it off with a plastic mallet.

Access to the rear clock casing allowed the bezel and clock crystal to be removed from the front of the clock by unscrewing the nuts holding them in place from the rear. Once these elements were removed the clock hands could be detached (see Figure 30). Firstly the second hand, which was press-fit on to the main motor shaft, was removed by gently pulling it off using a loop tool fashioned from a plastic covered paper clip, followed by the minute hand which was attached with a knurled ring to the cannon pinion shaft. The knurled ring was covered with multiple layers of silk and then loosened using pliers. Lastly the hour hand, also a press fit, was detached with gentle force using the paperclip loop.

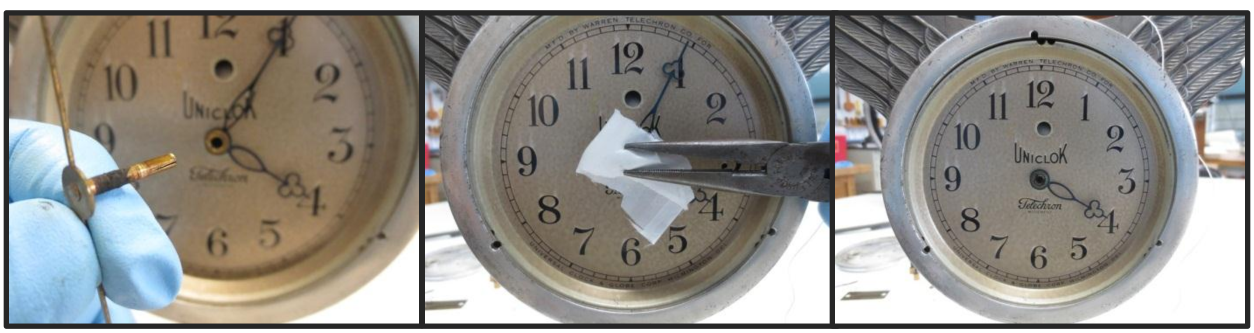


Figure 30: *During Treatment images showing the removal of the clock hands.*

The removal of the hands allowed the synchronous motor to be removed from the clock casing. Unscrewing the two machine screws holding the stator in place allowed the coil and motor to be ejected with ease (see Figure 31). The plate holding the dial train was then removed from the front of the clock casing by removing the four screws holding it in place.

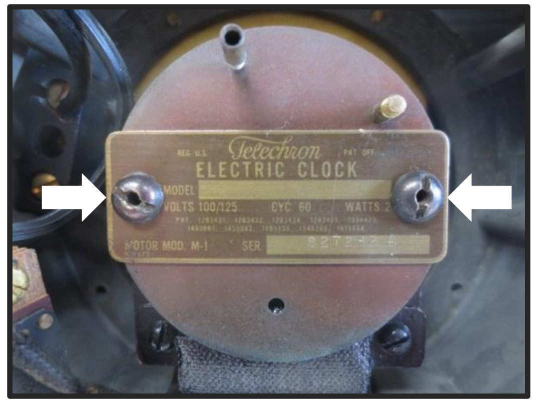


Figure 31: *The location of the two machine screws holding the stator and motor in place in the clock casing.*

The various components of the clock mechanism including the dial train and hands were cleaned with Stoddard solvent to reduce the accumulated grease and grime layer. The solvent was applied with a hand-rolled cotton swab and allowed to evolve off the surface.

Upon removal, the Telechron Type-B clock motor was found to be seized. Although there are a lot of recommendations for cleaning Telechron motors, both published (Linz 2001) and on enthusiast online forums, it was decided to purchase a replacement motor from a specialist. Telechron Type-B motors are sealed oil-filled units that require an involved and quite invasive process to recondition. The load and eventual wear on the motor, which not only powered the clock but also the globe mechanism, would likely have required that parts of the motor be replaced or refabricated. A replacement B-2 M-1 motor with a nine tooth pinion and a hollow shaft was bought from David Friedlund[9], a noted Telechron restorer, and installed in the Uniclok stator.

7.2 <u>Rewiring the Clock and Lamp</u>

The insulation on the wiring in the clock and lamp was compromised and necessitated the replacement of the wire in order to safely operate the instrument. Vintage two-conductor wiring was salvaged from an old GE clock and incorporated in to the Uniclok, linking the electric switch to the internal lamp (see Figure 32). Rayon-covered, faux-vintage, two-conductor wire was purchased from Sundial Wire and used to replace the degraded, main power cord. The Uniclok's existing plug was re-wired with the replacement cord. Raychem heat-shrink rubber tubing was used to manage the frayed ends of the brown rayon sheath (see Figure 33).

[9] Dave Friedlund sells restored Telechron motors on eBay under the handle "davefr_98". His website, www.telechronclock.com, has a wealth of information on the history of the Telechron motors, the various models and tips on their restoration.

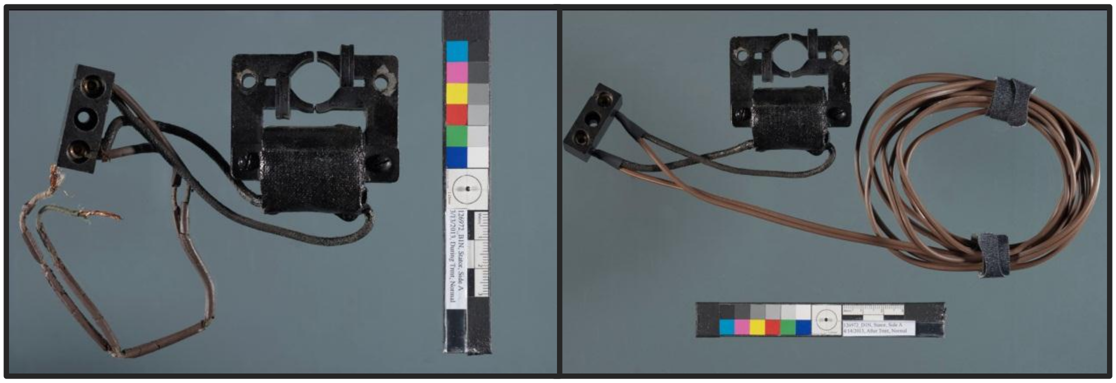


Figure 32: *Before (left) and after treatment images of the rewiring of the stator with brown two-conductor wire salvaged from a vintage GE electric clock. Note the significant degradation of the wire insulator in the image on the left.*

Figure 33: *Before (left) and after treatment images of the main power cord, which was replaced with a brown rayon-sheathed two conductor cord. The frayed ends of the rayon, where the sheath was removed to expose the plastic insulator, was managed with rubber heat-shrink tubing.*

7.3 Cleaning the Globe Hemispheres

Dirt and grime on the exterior of the globe was aqueously reduced with a 2% solution (w/v) of triammonium citrate applied with hand-rolled cotton swabs. Potential residue was cleared with two applications of deionized water.

7.4 Removal of the Globe Hemispheres from the Frame

The removal of the hemispheres was fraught with difficulty due to the brittleness of the cellulose nitrate substrate. The interior of the globe was accessed per the instructions contained in the Uniclok Handbook (Schulse 1931). The internal mechanism was heavily corroded such that none of the brass fittings and iron set screws could be moved. This was most likely due to the acidic environment created by the degrading cellulose nitrate globe and the cellulose acetate light shade contained inside. The corrosion of the mechanism prevented the upper hemisphere from being safely removed, and the position and fragility of the hemisphere prevented safe access to the mechanism. Attempts to remove the lower hemisphere from its supporting hub torqued the globe material resulting in the formation of two more cracks and the elongation of the existing crack. This event necessitated the cleaning of the break-edges before attempting to stabilize and consolidate the cracks. Approximately twenty minutes after the cleaning was finished, the globe broke into sixteen pieces and fell from its support (see Figure 34)

Figure 34: *The broken pieces of the globe positioned where they fell after cleaning with isopropanol (left), and the pieces collected and accounted for on the rightmost image.*

7.5 Reassembly of the Globe

The fragments of each hemisphere were reassembled using a combination of Paraloid B-72 (30 g of resin in 100 mL of a 2:1 mixture of acetone and ethanol), and small strips of Cerex secured in place across the break edges with Paraloid B-67 (20 g of resin in 90 mL of petroleum benzine and and 10 mL of xylenes). Cellulose nitrate is vulnerable to polar solvents so the B-72 mixture was dotted sparingly along the break-edges to hold the pieces together. B-67 was an obvious choice as the main consolidant given that it is soluble in low polar solvent, and would not affect the globe substrate. It also has a high glass transition temperature (50 °C) compared to other synthetic resins, which would make it less inclined to creep if an incandescent light source was used to illuminate the globe. The globe was then lined with Cerex gores adhered in place with B-67 (20g of resin in 90 mls of petroleum benzine and xylenes plus 2g of Kraton G 1257), further strengthening the globe. The cracks were coated with frisket on the exterior of the globe to reduce the potential for the B-67 resin to wick through the cracks by capillary draw and stain the paper. The addition of Kraton G 1257 to the resin was also an attempt to minimize the capillary draw by thickening the mixture.

When the globe was broken the majority of the damage was incurred at the two poles, leaving them inherently weak even after consolidation. This was somewhat inconvenient given that the poles were also the attachment points for the two hemispheres to the main frame, and as such required further strengthening before they could support their own weight and hold up to the torque of manually operating the globe. A combination of G-10 and clear polymethyl methacrylate (PMMA) was used to strengthen the poles. The PMMA was chosen for its clarity and would not be visible under transmitted light when the piece was operational. Washers were cut from G-10 and inserted in between the globe hubs and the globe. The washers were cut flush with the hubs so that they would not be easily viewable, but still large enough that they would provide adequate strength. 4 ½ inch wide PMMA squares were cut into discs and thermo molded to a stainless steel bowl that had the same spherical form as the inside of the globe. Holes were drilled in the G-10 and PMMA to accommodate brass machine screws, which were used to hold the assembly together (see Figure 36). The combined thickness of the materials required screws that were longer than those that originally came with the artwork. Replacement 6-gauge, flathead brass machine-screws were sourced from a local hardware store.

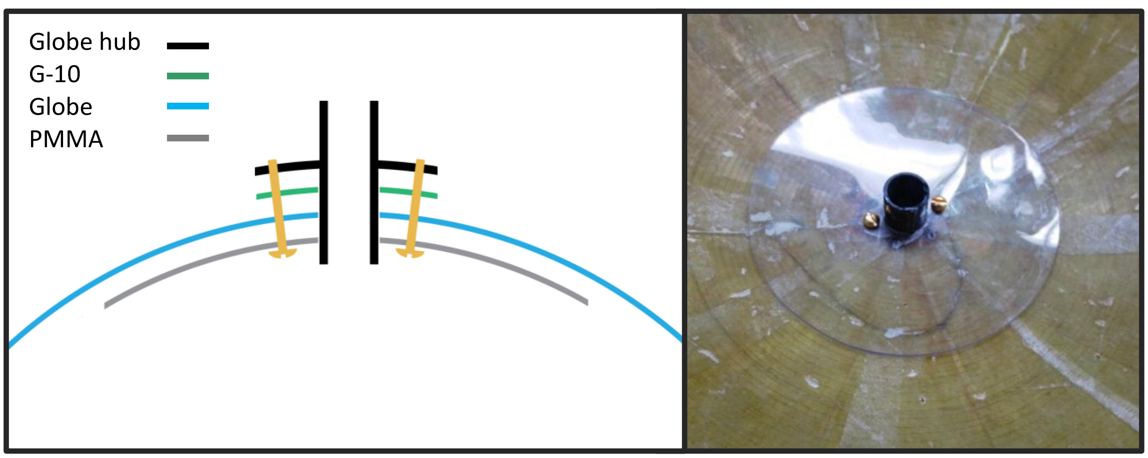


Figure 36: *The combination of materials used to strengthen the polar regions of each hemisphere. The diagram on the left is a cross-section of the polar region. The image on the right is an oblique view of the inside of the northern hemisphere, after the brace was assembled.*

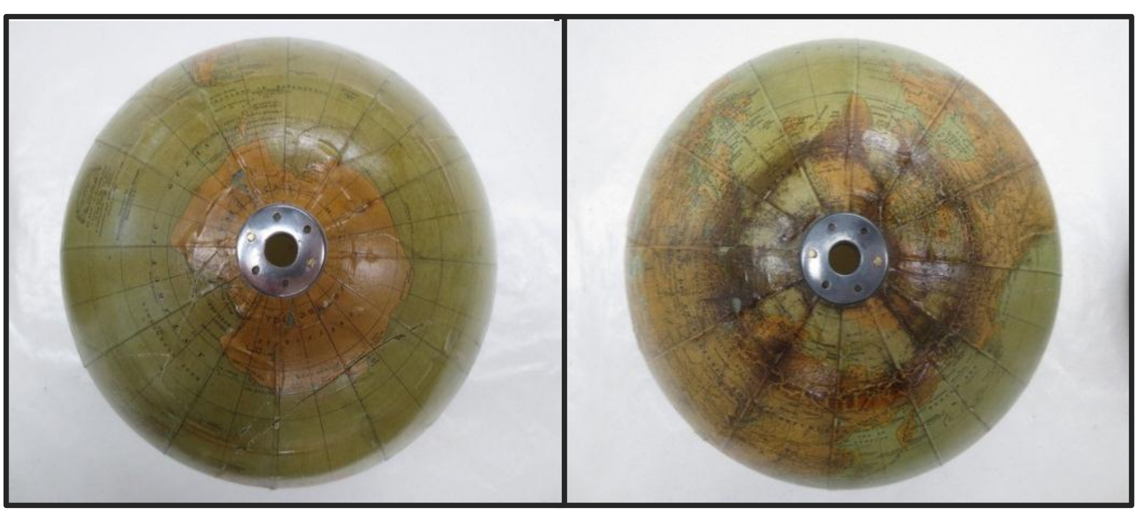


Figure 36: *The two globe hemispheres after consolidation.*

7.6 Compensating for Losses to the Globe Gores

While the globe had arrived at the Buffalo Start Art Conservation department with several losses to the paper gores, it sustained many more when the globe was damaged. The losses were filled with a heavy Japanese tissue toned with Golden acrylic paints. The losses were traced on to Mylar using a fine tipped pen and transferred to the toned paper using pin pricks. The pricked line was then torn by dragging the edge with a blunt scalpel. Each fill was applied with wheat-starch paste and, once dry, inpainted to match the surrounding gores using Golden acrylic paints. The fills were locally varnished with a1:1 mixture of Liquitex Soluvar gloss and matte varnishes.

With the polar regions of the globe now accessible the brown staining to the North Pole was reduced using isopropyl alcohol applied sparingly with Q-tips.

7.7 Disassembly and Cleaning of the Globe Mechanism and Lighting Rig

If the shattering of the globe had one silver lining it was that it gave unrestricted access to the internal mechanism. The globe's internal mechanism was highly corroded, which complicated its disassembly given that the many of the press-fit and threaded metal components had fused such that they could not be easily removed.

Where possible, corrosion was superficially reduced with Renaissance Metal De-corroder, applied with a rolled cotton swab. The gel was allowed to sit on the object for several minutes, before the corrosion product and residual cleaner were wiped off with a cotton swab and finally rinsed with deionized water to remove any residue of the de-corroder solution. In many cases this enabled access to the set-screws that held the various pieces of the mechanism together. With the larger portions of the mechanism disassembled, each individual piece could be broken down and the corrosion further reduced with steel-wool and petroleum benzine, and/or Autosol Polisher applied with Kimwipes and/or paper towels.

Three parts of the mechanism that were critical to the restoration of the globe's functionality proved the most problematic in their disassembly due to extensive corrosion. These were the lamp socket, the irreversible worm-gear driving the rotation of the lamp-shade, and the gear mechanism that translated the rotation of the globe to the internal mechanism. The lamp wiring insulation was compromised and in order to make the globe safely operational it had to be replaced. In order to access the lamp's electrical contacts the shell cap had to be removed from the socket. Unfortunately the screw thread connecting these two pieces was corroded and could not be twisted open as designed. To aid in the disassembly a simple clamp was constructed from a piece of wood by drilling a hole in it slightly larger than the diameter of the socket. The piece of wood was then cut in half bisecting the hole. Penetrating oil was dripped in to the seal of the shell cap join and the clamp was set in a bench vice around the socket. Rubber padded pliers were then used to safely twist the shell cap from the socket (see Figure 37).

Figure 37: *Process used to separate the lamp socket from the shell cap. The upper left image shows the clamp. The center image shows the oiled socket bound by the clamp. The upper right image shows the rubber padded pliers providing the torque necessary to separate the two parts. The lower image is an exploded view of the lamp showing the corroded thread and the degraded wire insulation.*

Unbinding the axle supporting the brass worm-gear from the heavily corroded zinc bracket was achieved using alternating applications of 3M hydrochloric acid and calcium carbonate solution (15% in deionized water). The hydrochloric acid was applied after wetting the axle with a droplet of ethanol in order to reduce the surface tension of the acid allowing it to flow into the join and preferentially etch away the zinc corrosion products (see Figure 38). The application of calcium carbonate solution neutralized the acid, and any residues were reduced with subsequent rinses with deionized water. The treatment proved very effective at quickly freeing the bound axle and restoring movement to the worm.

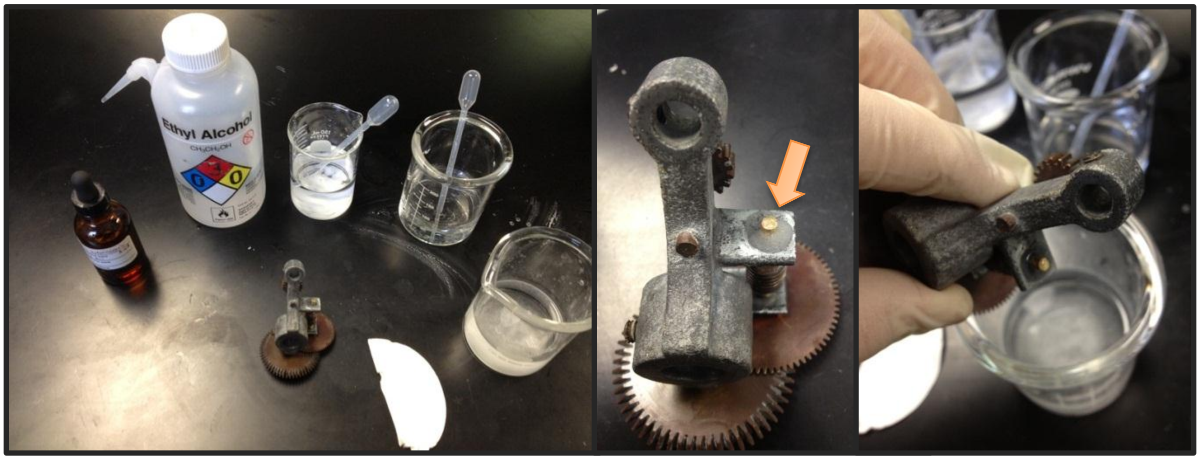


Figure 38: *Images showing how the bound axle was freed using ethanol, hydrochloric acid, calcium carbonate and deionized water. The central image shows the acid biting the zinc bracket around the brass axle. The rightmost image shows the piece after it was rinsed in calcium carbonate and deionized water.*

Separating the globe's upper hub/flange from the beveled gear was necessary in order to successfully reattach the upper globe hemisphere. The protruding hub was cast with a key that locked it in to a mortise in the collar of the beveled brass gear, thus it could not be twisted apart using padded pliers (see Figure 39). Simple tools were once again created to facilitate the separation. A clamp was made from a piece of wood with a bisected hole that was just wider than the diameter of the collar of the gear. Penetrating oils were flowed into the corroded join, and after the oil had sufficient time to soak in, the mechanism was secured in the clamp. A wooden dowel and a mallet were used to gently tap the bound hub from the brass gear.

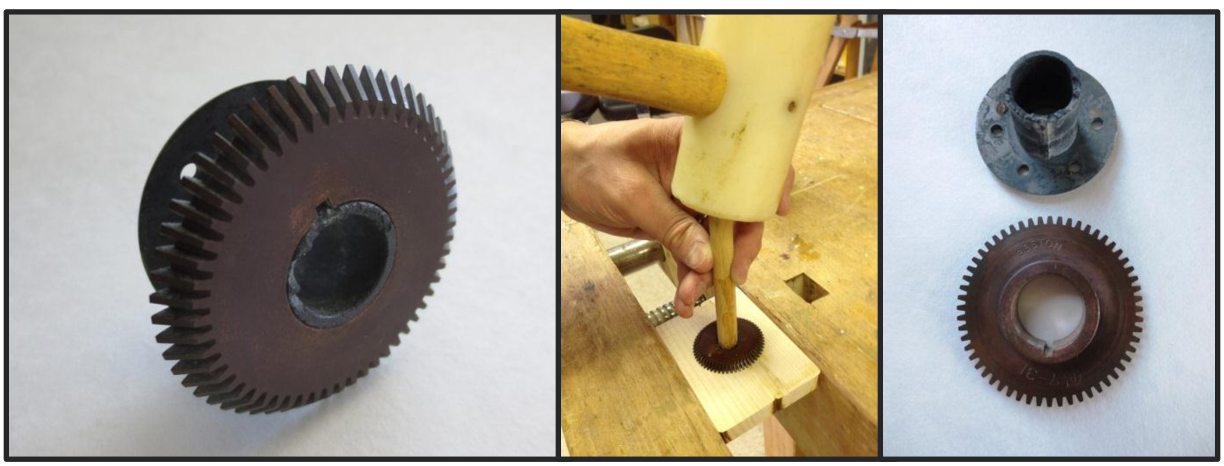


Figure 39: *Before, during and after images of the separation of the upper hub from the beveled gear.*

7.8 Reconditioning the Friction-clutches

An essential part of the globe's internal mechanism was the functionality of the two friction clutches. Combined with the irreversible worm-gears in the globe train, these features were designed to ensure that the manual operation of the globe did not interfere with, or bind the operation of the clock. Previously each clutch had one cardboard washer inserted into the mechanism. Both washers had disintegrated and were unusable. After cleaning the clutch mechanisms, Mylar washers were inserted into key positions to ensure that the clutches produced a smooth manual operation, while still providing enough friction to transfer mechanical motion from the clock movement. Four Mylar washers were inserted in to the lower clutch, and one was added to the central clutch (see figure 40).

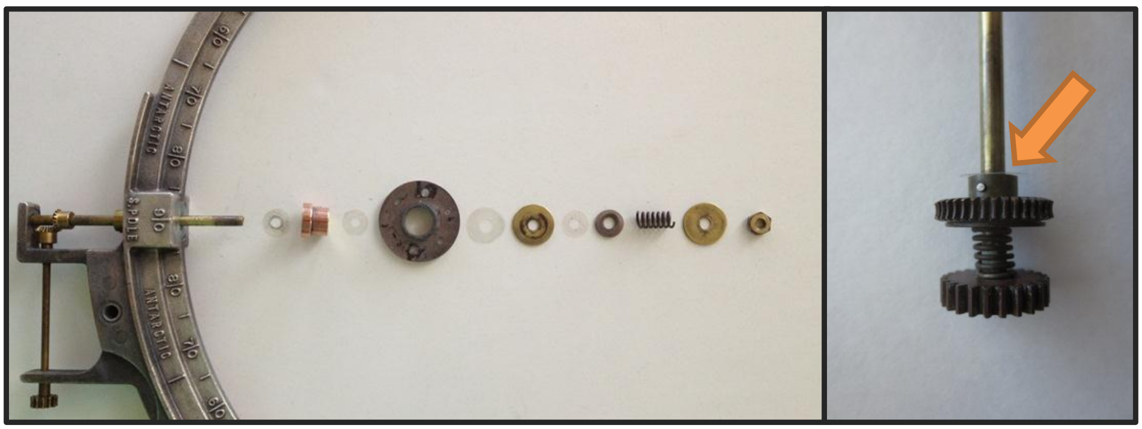


Figure 40: *The position of the Mylar washers that were added to the friction clutches as part of the treatment.*

7.9 Compensating for the Calottes

The choice to recreate the original date and time dials rather than attempt to conserve them raised some ethical issues, and the decision was not taken lightly. Herman Schulse's patent document clearly describes the function of the calottes in the following terms (Schulse 1934):

> *"By using a time dial and a calendar or date dial of transparent material and by making the bearings which support the clock of comparatively small dimensions, substantially no part of the surface of the map will be obscured and the map may be read even in the polar regions with convenience and facility."*

The calottes had degraded such that they were significantly deformed, and yellowed to the point that they had lost their transparency (see Figure 44). One could no longer view the polar regions of the map through the dials, nor could one view the lower time disc through the upper dial thus the ability to set the time and date on the globe had been comprised. Overall the deterioration of these forms had robbed them of their intended purpose, and if restoring the Uniclok's documented functionality was the goal then intervention was necessary.

The degraded cellulose acetate time and calendar discs were recreated from 1/16" thick poly(methyl methacrylate) (PMMA) sheet and thermo-formed using a laboratory oven and a spherical stainless steel mixing bowl as a mold. The PMMA was cut into circles with a band-saw using a simple circle-jig fashioned from a piece of scrap wood, a cam clamp and a screw (see Figure 41). A 9/16" hole was drilled in the center of each disc to accommodate the brass rings used to attach the calottes to the central shaft of the globe mechanism. The edges of the discs were smoothed with wet and dry abrasive papers (320 through 600 grit).

Figure 41: *Shaping the acrylic discs on the bandsaw with a simple jig (left), and drilling a hole in the center of the discs with a 9/16" spade bit in preparation for molding.*

The discs were heated for two minutes in a Fisher Scientific Isotemp lab oven set to 140 °C (the approximate glass transition temperature of PMMA), before being pressed against the outer form of a spherical stainless steel bowl (diameter 12"). Because the form was relatively simple, vacuum forming was not used; rather the disc was molded by hand into a shallow dome. A sheet of felt was used as a heat insulator and also served to protect the softened acrylic from scratches and fingerprints (see Figure 42).

Figure 42: *The acrylic discs were heated in a lab oven at 140 °C for 2 minutes (left) before being press formed against a stainless steel mixing bowl.*

The designs and indicators on the calottes were recreated digitally using Adobe Illustrator software (see Appendix 5). The fragments of the existing calottes, drawings from the Uniclok patent (Schulse 1931) and the technical drawing from the Albert Soeffing collection (see Figure 3) were used as visual resources for the design. The resulting image files were printed on to Papilio clear water-slide decal paper using a Ricoh Aficio MP3500 multi-function printer/copier. Krylon clear satin acrylic varnish was applied in a thin coat to fix the printed design to the decal and protect it from water immersion. Water slide decals are backed with a water-activated adhesive and a paper carrier. Applying the decals to their respective calottes was as simple as soaking them warm water until they released from their backing paper, and then laying on them on the surface of the PMMA dials. The decals were made from a thin film of n-butyl methacrylate, so their plasticity allowed them to be massaged over the very slightly domed forms (see Figure 43). As the decal adhesive dried it permanently adhered the designs to the new acrylic supports.

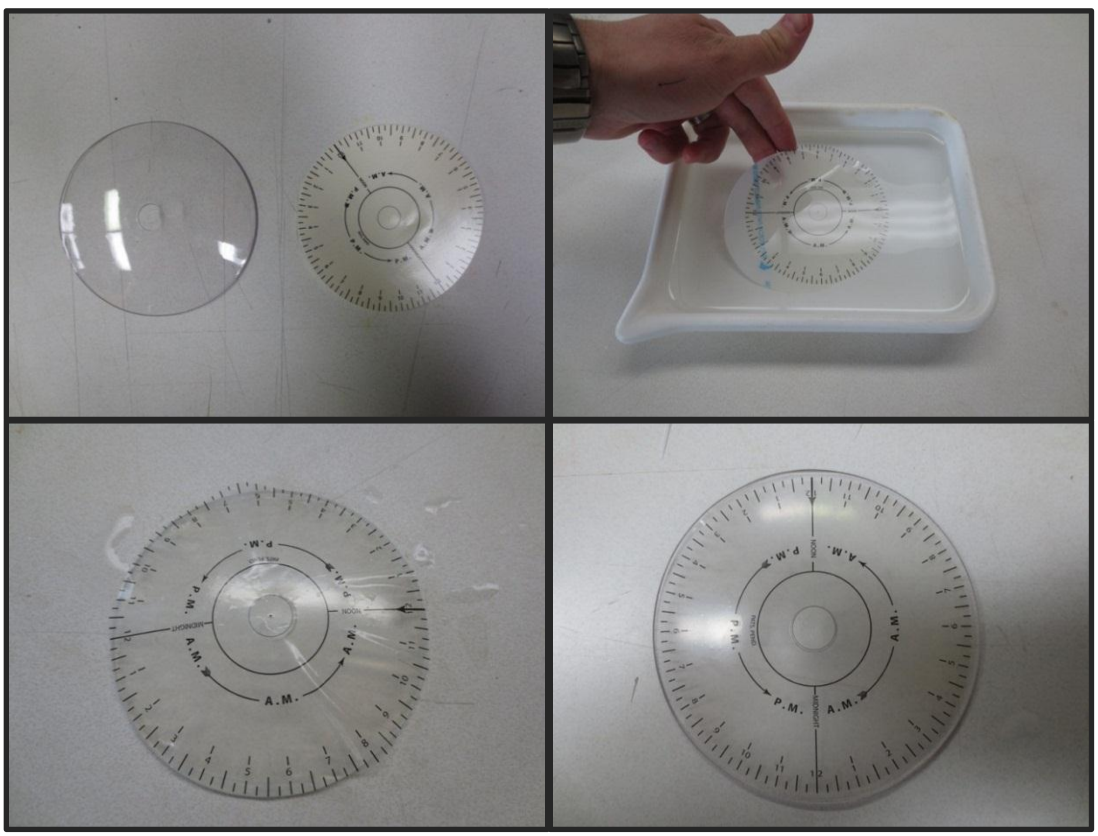


Figure 43: *The process of applying the water-slide decal to the formed acrylic calotte. Upper left: the printed decal, sealed with acrylic varnish, before water immersion. Upper right: the decal separating from its backing paper in a warm water bath. Lower left: the decal applied to the surface of the calotte before being massaged to form. Lower right: the finished calotte replacement.*

The brass hardware was removed from the original calottes and secured to the replacement discs with small dots of Paraloid B-72 to ensure good adhesion (see Figure 44). The date disc was drilled to accommodate two screws (for attachment to the frame) and the pinion that drove the time disc.

Figure 44: *The original, degraded cellulose acetate calotte discs (upper image) compared to their PMMA replacements.*

The original dials were separated from the piece and kept for posterity. They were stored in a box containing muslin bags filled with activated carbon scavengers, and A-D Strips (Image Permanence Institute) to monitor for acetic acid emissions.

7.10 Compensating for the Internal Shade

The original Uniclok had a ‘daylight/night discriminator’ made from cellulose acetate. This shade reduced the transmission of the internal light source such that half of the globe would appear in shadow, and combined with the internal rotating mechanism would indicate the position of the Earth’s shadow in relation to the seasons. Unfortunately the shade form had undergone severe deterioration, most likely the result of its proximity to a heat and light source, and the fact that it was in an enclosed space where its own degradation products (acetic acid), and that of the globe (nitrous dioxide and nitric acid) would have accelerated its decline. Once again the functionality of the object had been compromised and compensation was required to return the Uniclok to working order.

Information contained within the Uniclok’s patent document (US1959601) suggests that in its original form the lamp shade would have been a translucent blue or purple (Schulse 1934). This choice in color and light transmission allowed geographical features on the shaded side of the globe to still be discernible. Unfortunately due to the cost of materials a translucent blue or purple plastic could not be used in this treatment and an opaque black piece of black PMMA sheet (1/8” in thickness) was used as an alternative.

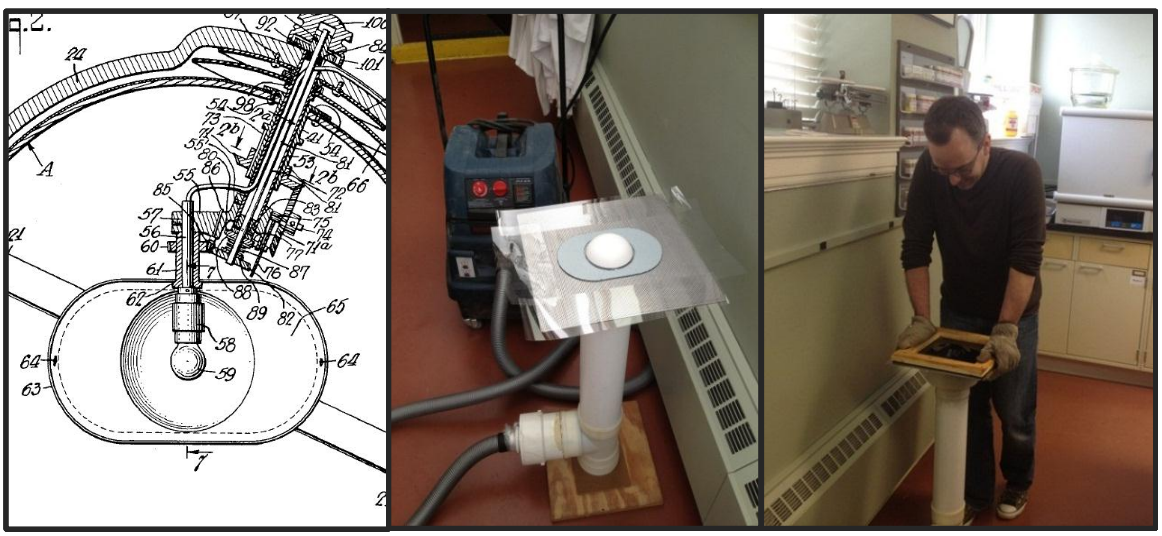


Figure 45: *The leftmost image is a drawing from the Uniclok patent indicating how the original shade might have looked. The central image shows the mold and suction platen used for the vacuum forming. The rightmost image shows the vacuum-forming in action.*

The degraded form was recreated using a makeshift vacuum molding apparatus. The PMMA sheet was cut to a 12” square and tacked to a wooden strainer. The plastic was heated for twenty-five minutes in a Fisher Scientific Isotemp lab oven set to 150 °C. This was slightly higher than the published glass transition temperature (T_g) of PMMA, but tests showed that the sheet required a higher temperature to achieve the appropriate level of plasticity. The heated

PMMA was then vacuum-formed over a mold constructed from matboard and a plaster-of-Paris dome. The molding apparatus used a Ryobi Shopvac as the vacuum source and a suction platen made from PVC tubing and perforated aluminum (see Figure 45). The PMMA form was then cut to shape with a bandsaw and drilled to accommodate the split-pins used to hold the shade in place on the internal frame (see Figure 46).

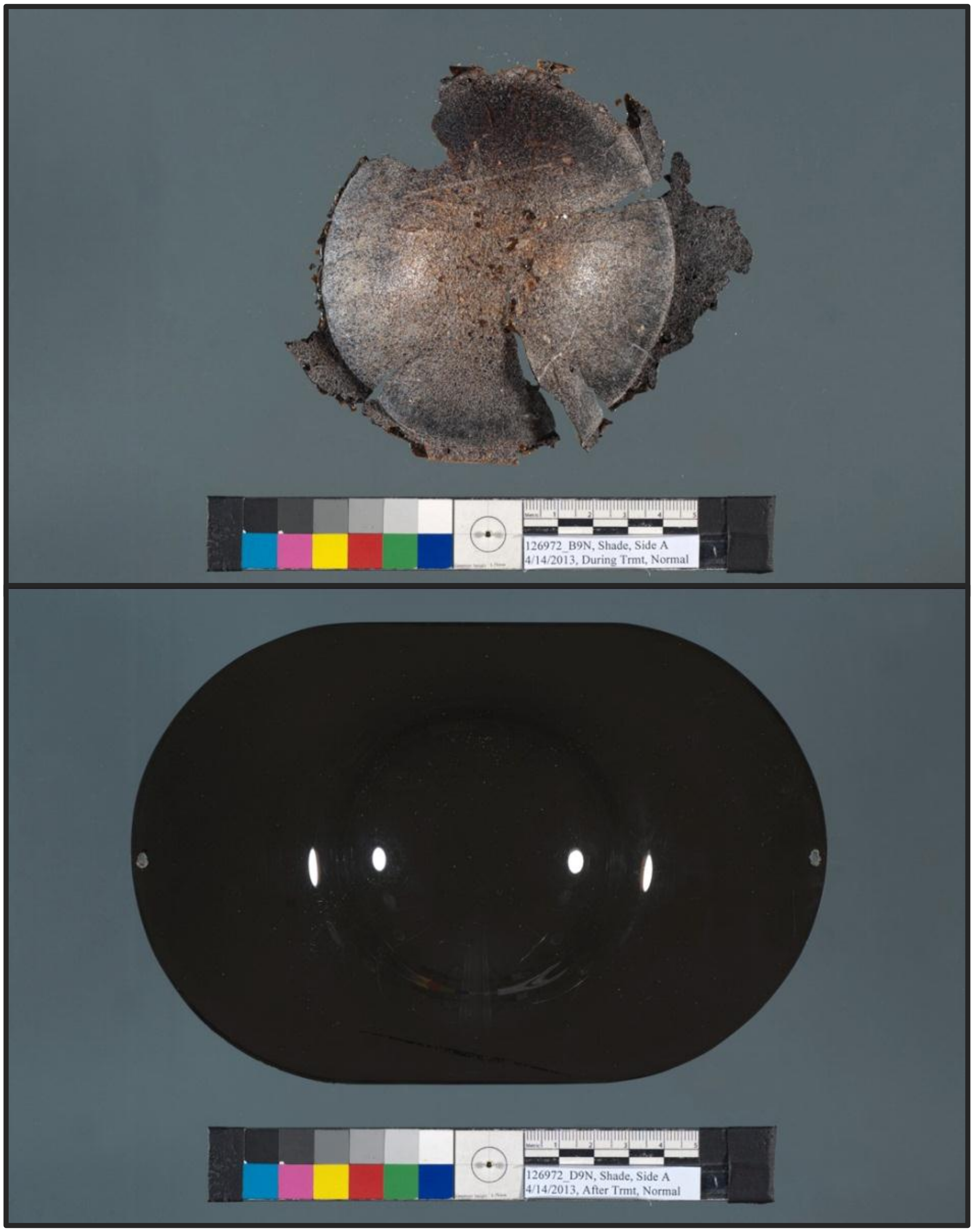


Figure 46: *The original, highly degraded cellulose acetate daylight/night discriminator (upper image) compared to its black PMMA replacement.*

7.11 Replacing the Light Source

When the Uniclok arrived at the Buffalo State Conservation Department it contained a 5 Watt incandescent light bulb with a broken filament. After reviewing alternative light sources and investigating the effects of different wavelengths of light on nitrocellulose and cellulose acetate, a similar incandescent bulb was used as a replacement. Reliable, white light-emitting diodes (LEDs) are a relatively new feature on the lighting market, and they show promise as a long-life, low-maintenance lighting solution. With regard to the Uniclok, an LED light source could have been ideal given that they can last many years longer than an incandescent bulb. This would translate to less handling of the fragile globe due to the decreased frequency of light-bulb exchanges. The problem observed with the potential LED replacements was that they had a sharp emission of light in the blue region of the visible spectrum (~455 nm), as shown in the spectral power distribution (SPD) graph in Figure 47. Cellulose nitrate is particularly sensitive to shortwave visible light and ultraviolet radiation (Selwitz, 1988), which will generally result in the formation of chromophores (Shashoua, 2008) and a yellow discoloration. Higher energy radiation (UV with a wavelength less than 360 nm) has a more damaging effect and will also result in chain cleavage of the cellulosic polymer and embrittlement of the plastic. The use of the LED light sources available to us was deemed inappropriate given the potential effects of shortwave visible light on the globe substrate. The incandescent bulbs, although they have a higher heat signature, had no potentially damaging emissions in the shortwave visible spectrum.

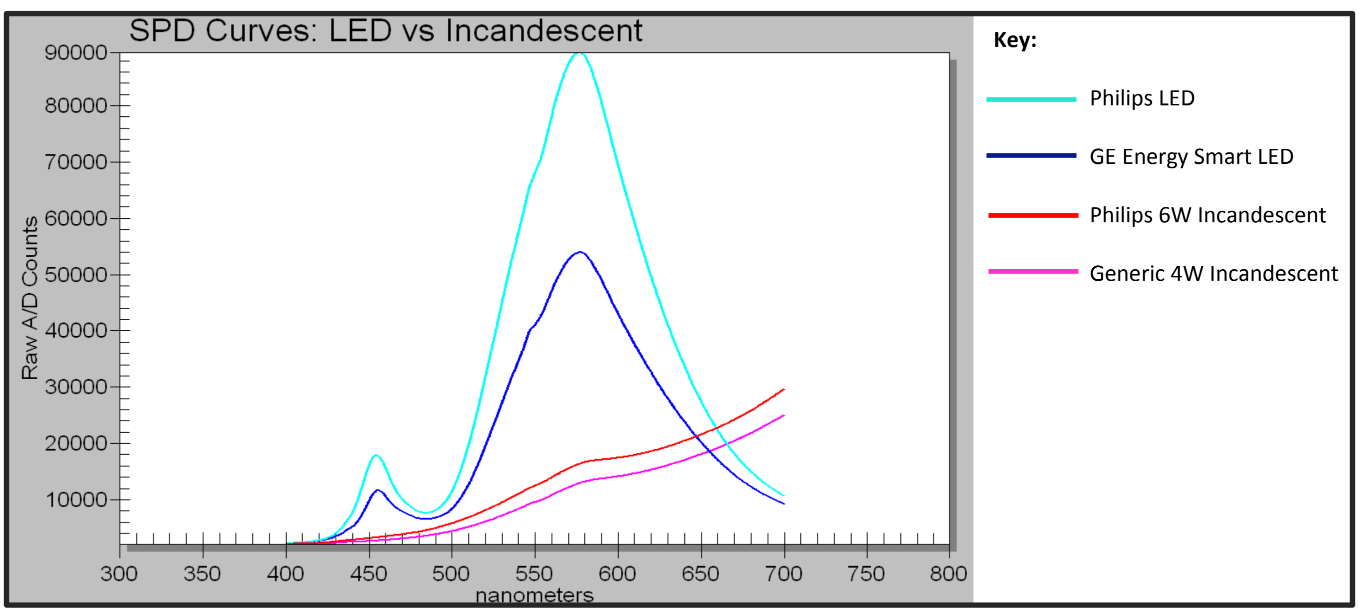


Figure 47: *A comparison of the measured SPD curves for four consumer-ready LED and incandescent light sources.*

Figure 48: *After-treatment images of the front of the Uniclok. The left image shows the globe in normal illumination; the metal components have been cleaned and polished, the globe has been reassembled and cleaned, and the time and date calottes have been replaced. The image on the right showcases the restored globe's functionality; the internal light source transmits through the globe's translucent nitrocellulose material but is eclipsed on one side to convey the sense of the Earth's shadow.*

8. Conclusions

The functionality of the Uniclok instrument, as detailed in Herman Schulse's 1934 patent document, was restored to working order (see Figure 48). Replacement of the degraded electrical wiring ensured that the piece could be used safely, while the choice of a rayon sheathed power cord, and brown two-conductor wiring was appropriate for an electrical instrument made in the 1930s. The clock and globe dial trains were cleaned and unbound. The reconditioned Telechron B-2 rotor provided a smooth and quiet movement, and in turn powered the reduction train spinning the globe one revolution per day. Assuming that the flange on the lower hemisphere maintains a tight fit with the upper hemisphere, the reduction train in the internal mechanism will rotate the daylight/night discriminator about the incandescent light source at a rate of one full revolution every three hundred and sixty-five days. Also consistent with its original design, the globe and the internal shade may both now be turned manually without impacting the clock movement. Thus the Uniclok was once again able to provide accurate time and date information while simulating daylight and night as they exist at a given point in time.

Cleaning and polishing the clock casing, clock base, calendar ring and globe frame significantly improved the appearance and cleanliness of the object, although it exposed a history of over-cleaning especially to the silvered base. Sealing the polished metal decreased the oxidation potential of the metal surfaces, and in turn helped to reduce the maintenance of the object on-going.

Compensation for the highly degraded cellulose acetate components of the Uniclok was successful both in terms of restoring lost functionality and improving the overall appearance of the globe. The replacement time and date dials, and daylight/night discriminator, fabricated in PMMA, fulfilled the functionality described in Herman Schulse's Uniclok patent document; the map details at the North Pole could be read through the stacked time and date dials, the time dial could be read through the date dial, and the black light shade cast an appropriate shadow on half of the globe at any one time. Transferring the digitally reconstructed calotte markings to the calottes using water slide decals allowed them to be finely rendered, accurately reproducing the look and feel of the commercially printed cellulose acetate dials. The techniques used to fabricate these replacement parts proved that simple plastic forms could be safely reconstructed in a conservation lab setting, and produced at low cost.

Scientific analysis of the Uniclok materials helped to uncover some of the manufacturing history of the globe, and its processes of deterioration. The major structural components of the object were identified as a zinc-rich casting alloy using XRF. This was neatly married to the

Sterling Die-casting Co.'s maker's mark giving clear evidence of how and where the metal parts of the object were created. The identification of the degraded plastics demonstrated how the by-products of their decay had had a deleterious effect on the globe's materials. This included not only the autocatalytic deterioration of the cellulose acetate components, but the heavy corrosion of the internal mechanism and electrical wiring.

The damage incurred by the globe during treatment was unfortunate, and ultimately detracted from the overall experience of the globe given that the number of cracks visible with transmitted light increased over the course of treatment. The breakage did however provide a valuable lesson and some additional treatment opportunities. Had the globe not broken it is doubtful that the internal mechanism could have been successfully reconditioned and documented. Certainly the fabrication of the time and date dials would not have been possible with the globe hemispheres in place, and finding a solution to mend the globe that considered cellulose nitrates' sensitivities would not have been required. All of these activities were important learning experiences that leveraged two years of study and practice at the Buffalo State Art Conservation program.

9. Future Research

To fully determine the original appearance of the Uniclok object closer attention needs to be paid to the nickel colored regions of the clock casing. While analyzing and cleaning these parts of the object suspicions were raised that they may have been the result of an organic coating applied either over the finished metal, rather than an electro-deposited nickel coating. This needs to be investigated further. The coating has been eroded by cleaning, and some areas have been stripped to the base metal. Subsequent treatments, if not conducted with care, could erase all evidence of this decorative layer and cause a dramatic departure from the object's intended finish. A sample of the suspected coating could be taken from the clock adjustment dial[10] on the rear of the Uniclok and analyzed with transmission FTIR microscopy, or GC-MS.

[10] This dial was intentionally left in its original state, and was neither cleaned nor sealed in wax or Agateen lacquer.

10. Acknowledgements

Buffalo State College Art Department

Jonathan Thornton, Professor and advisor, Objects Conservation
Dr. Corina Rogge, Andrew W. Mellon Professor in Conservation Science
Dr. Aaron Shugar, Professor, Conservation Science
Judith Walsh, Professor, Paper Conservation
James Hamm, Professor, Paintings Conservation
Jiuan Jiuan Chen, Professor, Examination and Documentation
Lucy Skinner, Mellon Teaching Fellow, Objects Conservation
Patrick Ravines, Director and Associate Professor
Thanks to every member of the Buffalo State faculty, without whose advice and support I could never have completed this project.

Assistance Researching the History and Significance of the Uniclok Object

Dr. F. Christopher Tahk, Professor/Director Emeritus, Conservation Science
Chris' advice, vast knowledge and endless willingness to help were an inspiration throughout this project.

Advice on Globe Restoration

T.K McClintock, Owner and Chief Conservator, Studio TKM

Winterthur Library

Debra Hess-Norris, Director WUDPAC Program
Jeanne Solensky, Winterthur Librarian, Joseph Downs Collection of Manuscripts and Printed Ephemera

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12. Materials and Sources

ACRYLIC SHEET 1/8” black polymethyl methacrylate. Supplied by Great Lakes Plastic: 2371 Broadway St Buffalo, NY 14212. Ph: (716) 896-3100 Web: www.greatlakesplastic.com

ACRYLIC SHEET 1/16” clear polymethyl methacrylate. Found in Buffalo State Art Conservation workshop. Supplier unknown.

AGATEEN AIR DRY LACQUER #27 - cellulose nitrate based lacquer. Agate Lacquer Tri-Nat, LLC, 824 South Avenue Middlesex, NJ 08846, Ph: 732- 968-1080. Available from Talas 330 Morgan Ave Brooklyn, NY 11211; Ph: 212-219-0770.

AGATEEN AIR DRY LACQUER THINNER #1 – proprietary mix of toluol, n-butyl alcohol, n-amyl acetate , n-Butyl acetate, n-Propyl acetate. Agate Lacquer Tri-Nat, LLC, 824 South Avenue Middlesex, NJ 08846, Ph: 732- 968-1080. Available from Talas 330 Morgan Ave Brooklyn, NY 11211; Ph: 212-219-0770.

ARM AND HAMMER SUPER WASHING SODA: solution of sodium carbonate in deionized water (15% w/v). Purchased from Wegmans.

AUTOSOL METAL POLISH. Autosol LLC, P.O. Box 340358, Austin, TX 78734. Ph: 1800-314-5545. Web: http://autosol.com.

BROWN, 2 CONDUCTOR, 18-GAUGE, PVC-INSULATED, RAYON-COVERED WIRE, Sundial Wire, PO Box 803, Northhampton, MA 01061. Ph: 413.582.6909. Web: www.sundialwire.com.

BUTCHER’S BOWLING ALLEY WAX (CLEAR) - a blend of carnauba and microcrystalline waxes with mineral spirits as a softening agent. Available from Conservation Support Systems, P.O. Box 91746, Santa Barbara, CA 93190. Ph: 1800-482-6299. Web: www.conservationsupportsystems.com

CEREX (spun bonded nylon, 0.4 oz./sq. yd.) Talas 330 Morgan Ave Brooklyn, NY 11211; 212-219-0770

GREEN FELT, Vintage Wire and Supply, 416 Milan Avenue P.O. Box 864, Amherst, OH 44001. Web: http://vintagewireandsupply.com

KRATON G 1257 (copolymer of polystyrene and poly(ethylene butylene) Shell Chemical Co., 1415 West 22nd St., Oak Brook, Illinois 60522-9008. available from Talas 330 Morgan Ave Brooklyn, NY 11211; 212-219-0770

LIQUITEX SOLUVAR GLOSS PICTURE VARNISH (a mixture of n-butyl and isobutyl methacrylates) Binney & Smith Inc., Easton, PA 18044.

LIQUITEX SOLUVAR MATTE PICTURE VARNISH (a mixture of n-butyl and isobutyl methacrylates) Binney & Smith Inc., Easton, PA 18044.

MYLAR Type D [clear] (polyester film), 5 mil thick (1 mil = .001") *now known as Mitsubishi Hostaphan 43SM or Dupont Melinex type 516 or 456, since the brand* <u>*Mylar-D*</u> *has been* *discontinued as of 2001*; available from Talas 330 Morgan Ave Brooklyn, NY 11211; 212-219-0770.

PAPILIO CLEAR LASER DECAL PAPER. n-Butyl methacrylate, self-adhesive, water-slide decals. HPS Papilio, P.O. Box 855 Rhome, TX 76078. Ph: 940-627-0112. Web: www.papilio.com

PARALOID B-67 (isobutyl methacrylate) Rohm & Haas, Philadelphia, PA.

PARALOID B-72 (a copolymer of ethylmethacrylate and methyl acrylate) Rohm & Haas, Philadelphia, PA.

PHILIPS 6W CLEAR S6 INDICATOR BULB. Acquired from Home Depot, 2100 Elmwood Ave, Buffalo, NY 14207. Ph: 716-871-8800. Web: www.homedepot.com.

PRECIPITATED CHALK – precipitated calcium carbonate. L. Cornelissen & Sons, 105 Great Russell St, London, United Kingdom. Ph: +44 020 7636 1045. Web: www.cornelissen.com

RAYCHEM HEAT-SHRINK TUBING, Tyco Electronics Corporation, 300 Constitution Drive, Menlo Park, CA 94025-1164. Ph: 650-361-3333

RENAISSANCE METAL DE-CORRODER: An amine complex of hydro-oxycarboxilic acid in aqueous solution. Available from Talas. 330 Morgan Ave, Brooklyn, NY 11211; Ph: 212-219-0770.

RHOPLEX N-580 ([butyl acrylate homopolymer] emulsion) Rohm & Haas, Philadelphia, PA. Available from Talas 330 Morgan Ave Brooklyn, NY 11211; Ph: 212-219-0770.

TELECHRON B-2 M-1 ROTOR – Reconditioned Telechron B-2M-1 rotor - disassembled, cleaned, rebushed and lubricated by David Friedlund, 36006 SW Bald Peak Rd, Hillsboro, OR, 97123. Web: www.telechronclock.com.

13. Autobiographical Statement

Aaron Burgess received a Bachelor's of Fine Arts from the Elam School of Fine Arts, University of Auckland, where he studied painting, art theory, and art history. After graduating in 1999 he started a ten year career in information technology. It was not until 2009 that Aaron opted to pursue art conservation. He interned at the Denver Art Museum (DAM) for nine months before taking on a role as a conservation technician the following year, all the while completing chemistry courses at the University of Colorado, Denver. While at DAM he had the opportunity to survey and treat a broad range of materials and artworks including Native American textiles and beadwork, pre-Columbian burial ceramics, WPA era paintings and murals and variable media installations. Aaron's primary interests are in modern and contemporary materials, and media preservation. In the summer of 2012 he interned at the Detroit Institute of Arts treating objects in their modern and contemporary collection, and also surveying pieces in their variable media collection. Aaron will complete a graduate internship at The Henry Ford Museum from September 2013 through September 2014. He will receive his Master of Arts and Certificate of Advanced Study in Art Conservation, specializing in objects conservation, from Buffalo State College in September 2014.

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27. XRF spectra comparing a worn region of the Uniclok clock casing to an area that had a nickel coloring. The spectra indicate that the clock casing is not nickel plated.

28. Images of a Uniclok Floor Model 121C. Image source: <www.ebay.com/itm/Rare-Art-Deco-UNICLOK-World-Globe-Floor-Clock-Circa-1930-Telechron-Illuminated-/380610454791?pt=LH_DefaultDomain_0&hash=item589e26a507>
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15. D19TR: *Uniclok Table Globe*, front view, after treatment, transmitted illumination.
16. D20TR: *Uniclok Table Globe*, proper left view, after treatment, transmitted illumination.
17. D21TR: *Uniclok Table Globe*, back view, after treatment, transmitted illumination.
18. D22TR: *Uniclok Table Globe*, proper right view, after treatment, transmitted illumination.

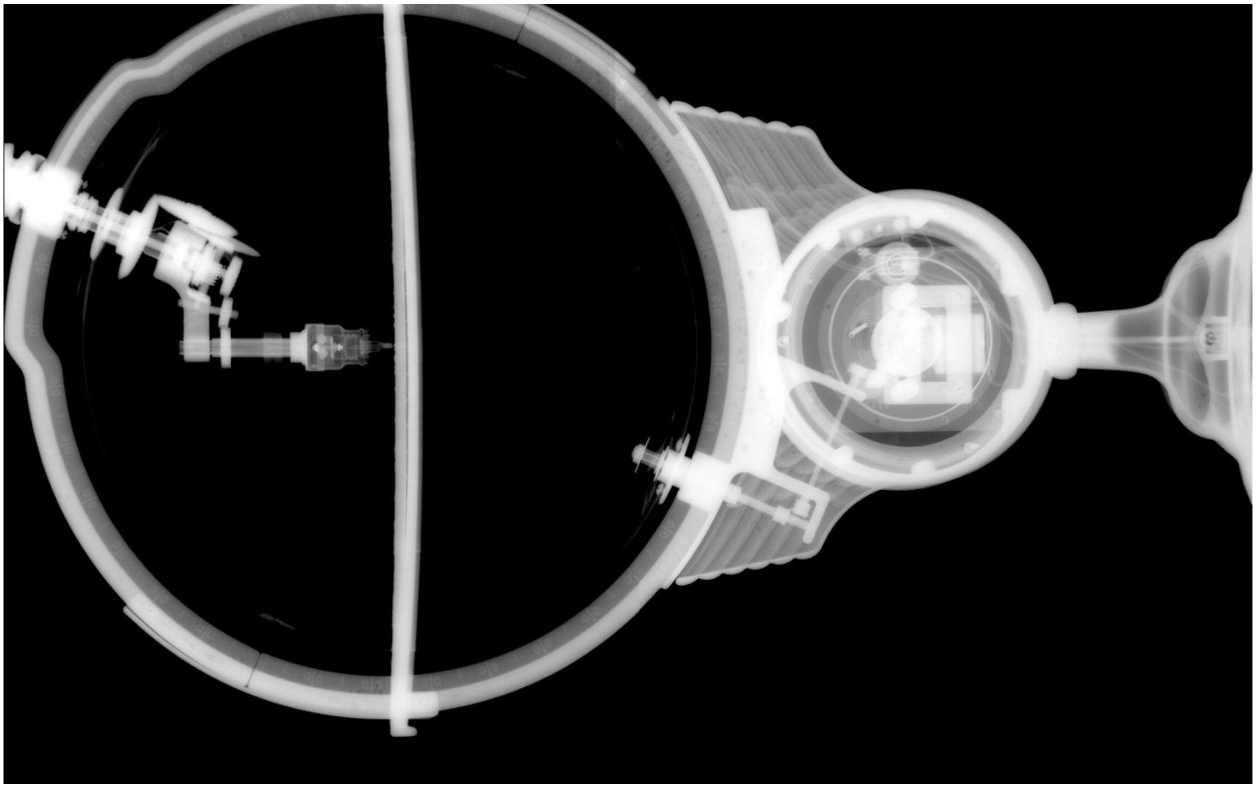


Plate 2: *Coronal view, before treatment, X-radiograph.*

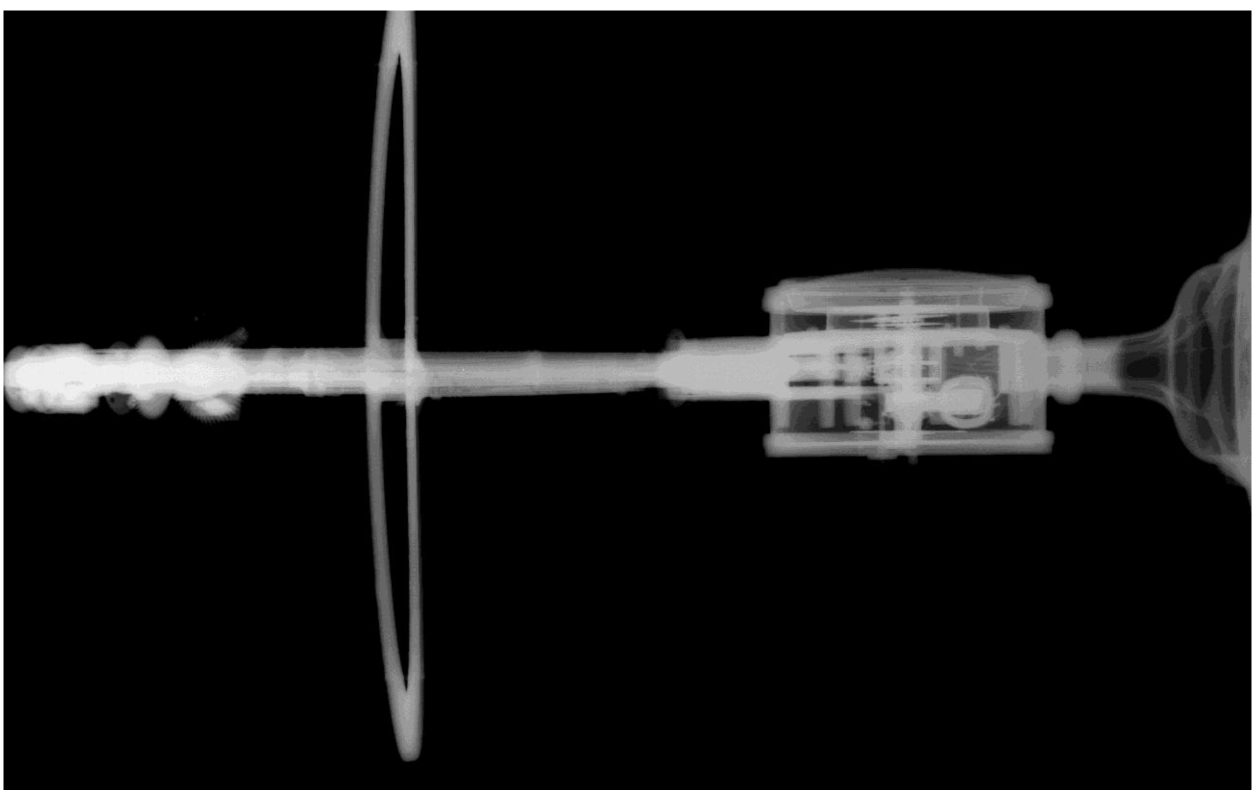


Plate 1: *Sagittal view, before treatment, X-radiograph*

Plate 4: *Front, after treatment, normal illumination*

Plate 3: *Front, before treatment, normal illumination*

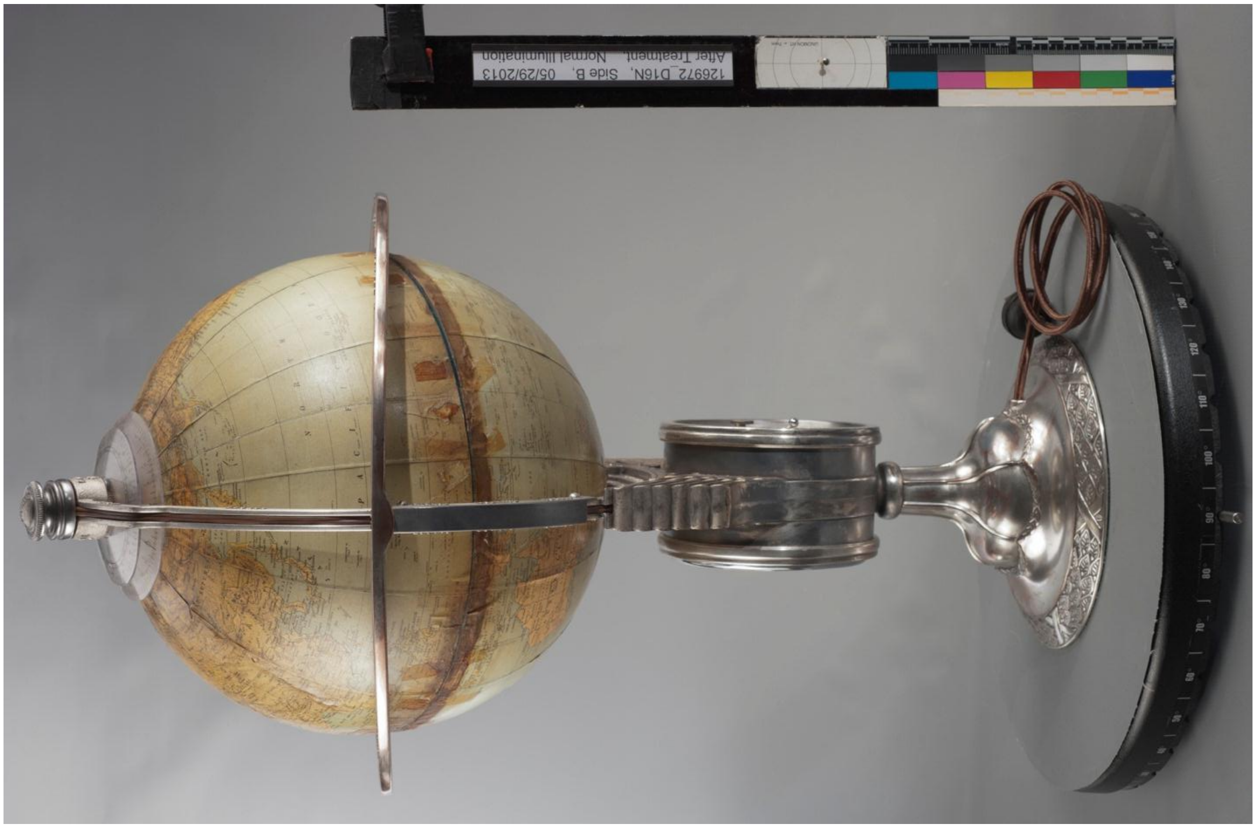


Plate 6: *Proper left, after treatment, normal illumination*

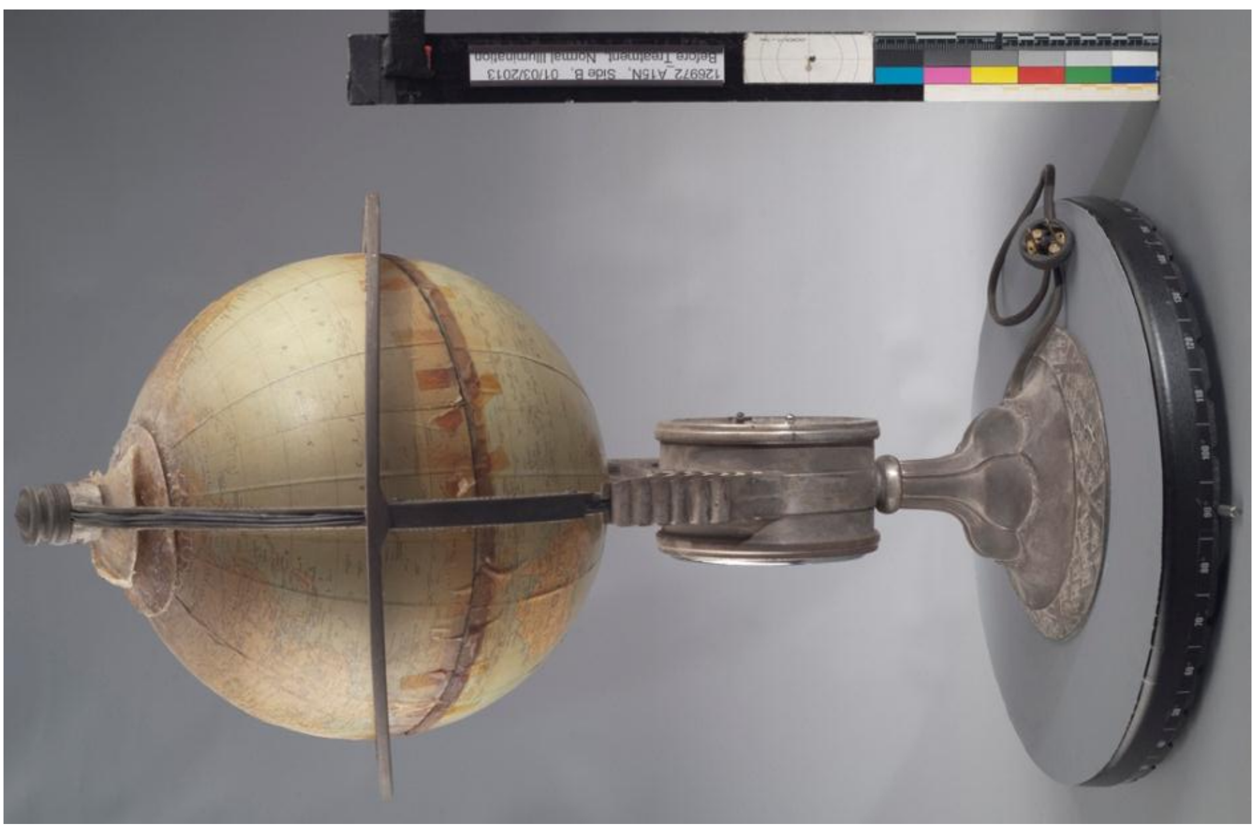


Plate 5: *Proper left, before treatment, normal illumination*

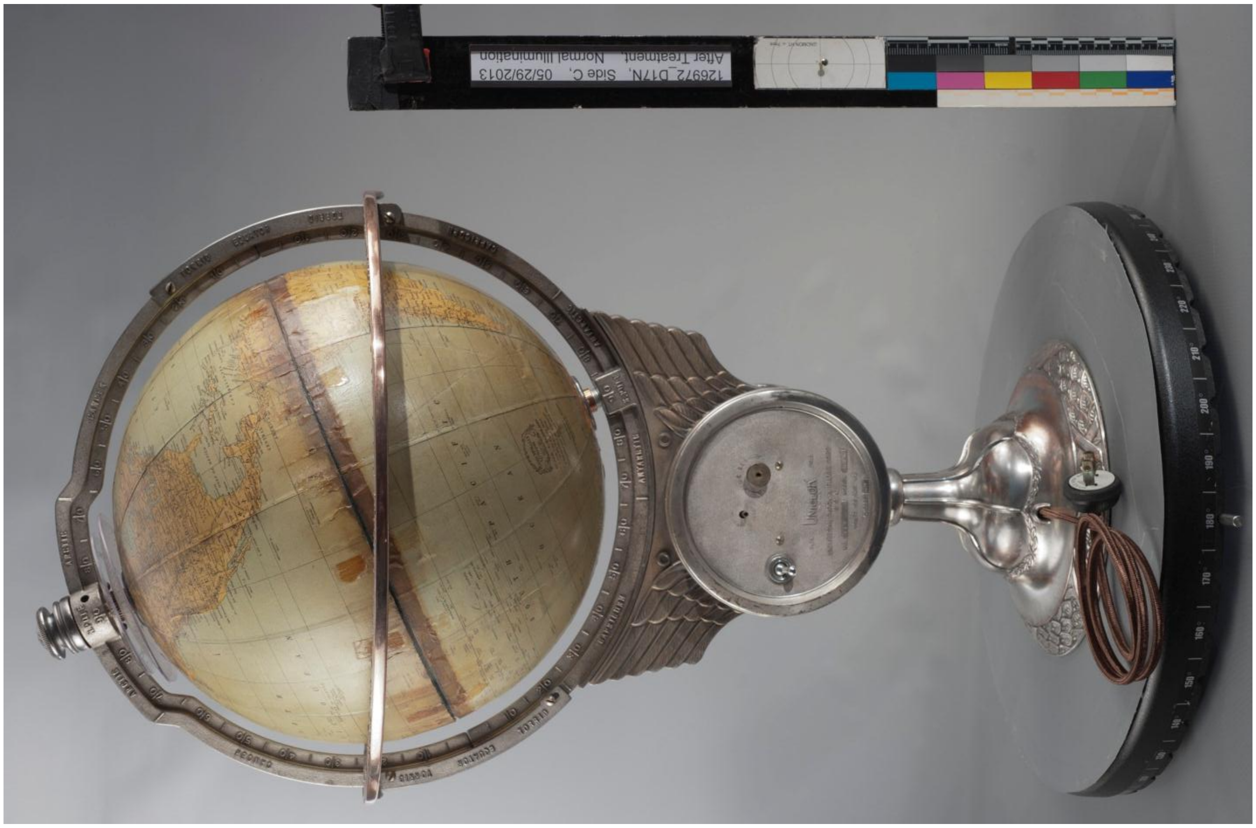


Plate 8: *Back, after treatment, normal illumination*

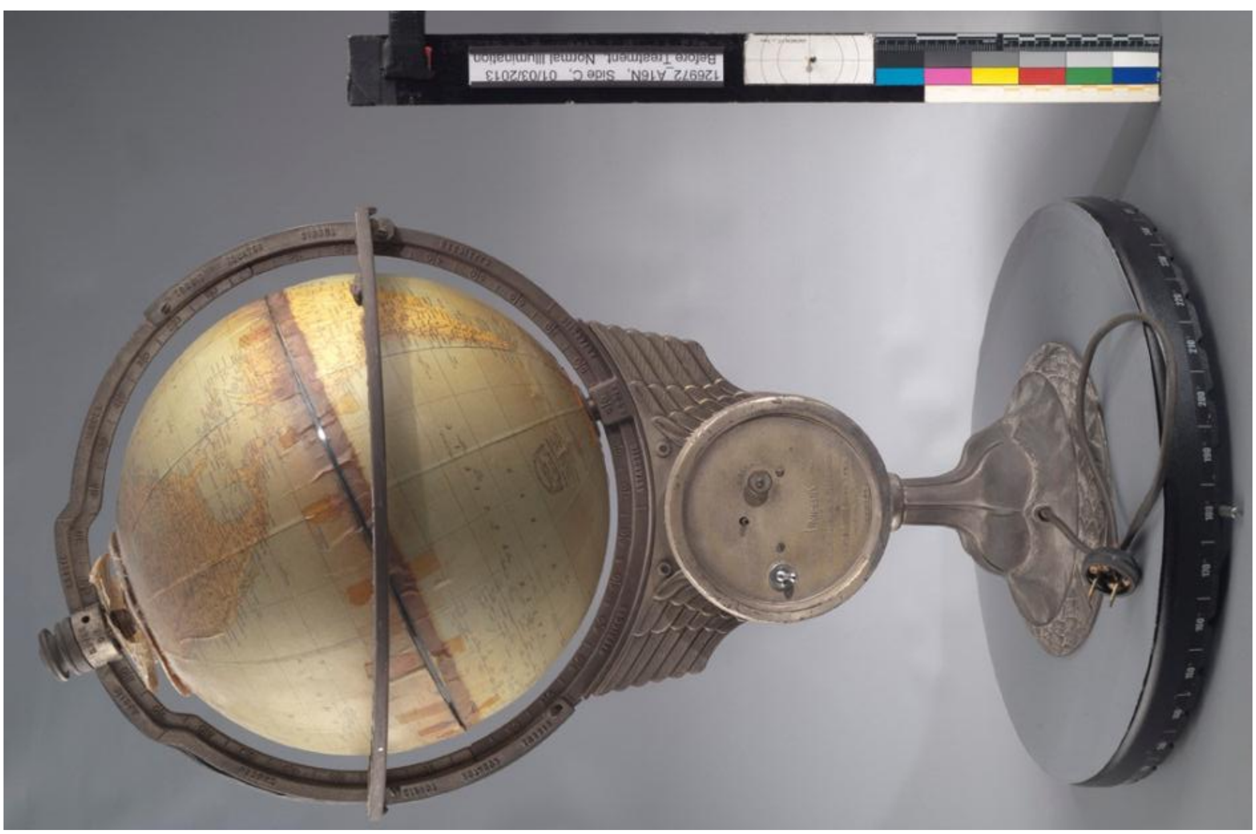


Plate 7: *Back, before treatment, normal illumination*

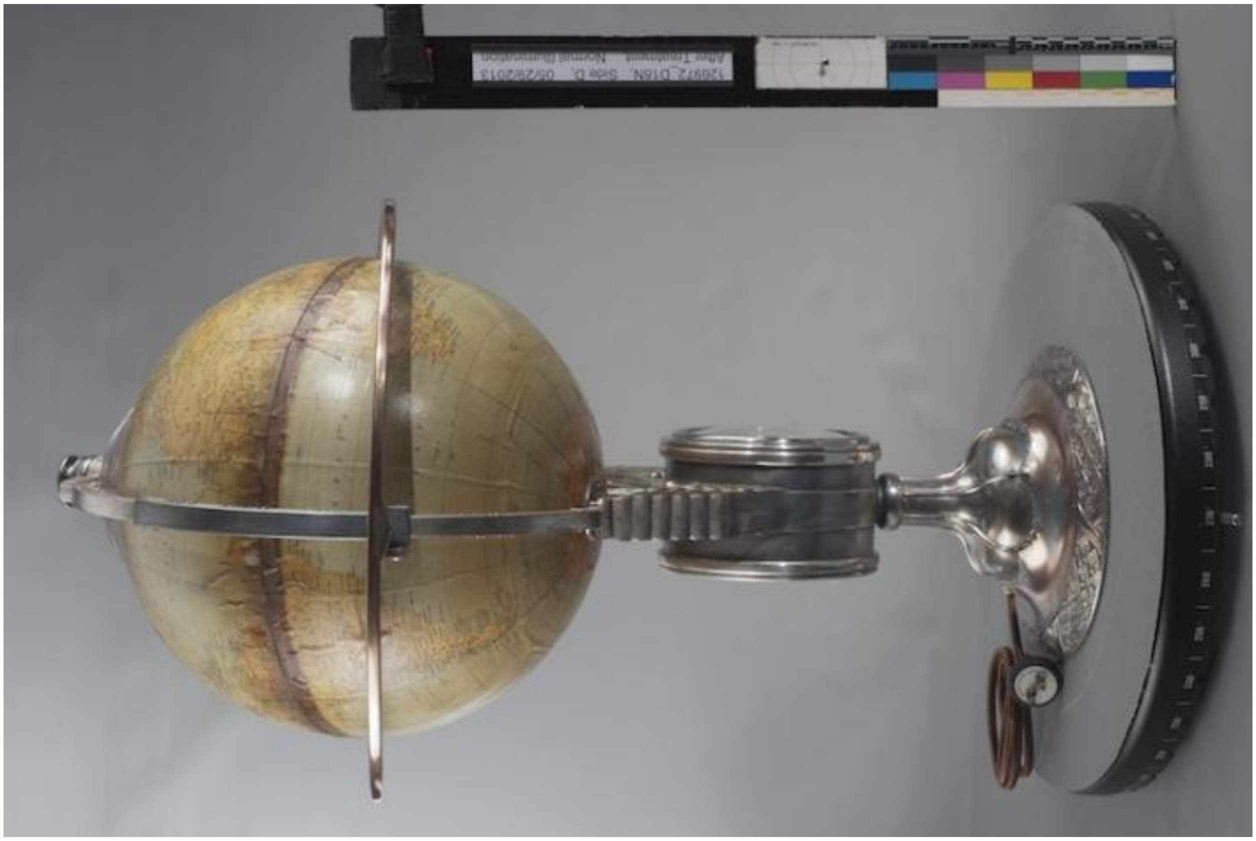


Plate 10: *Proper right, after treatment, normal illumination*

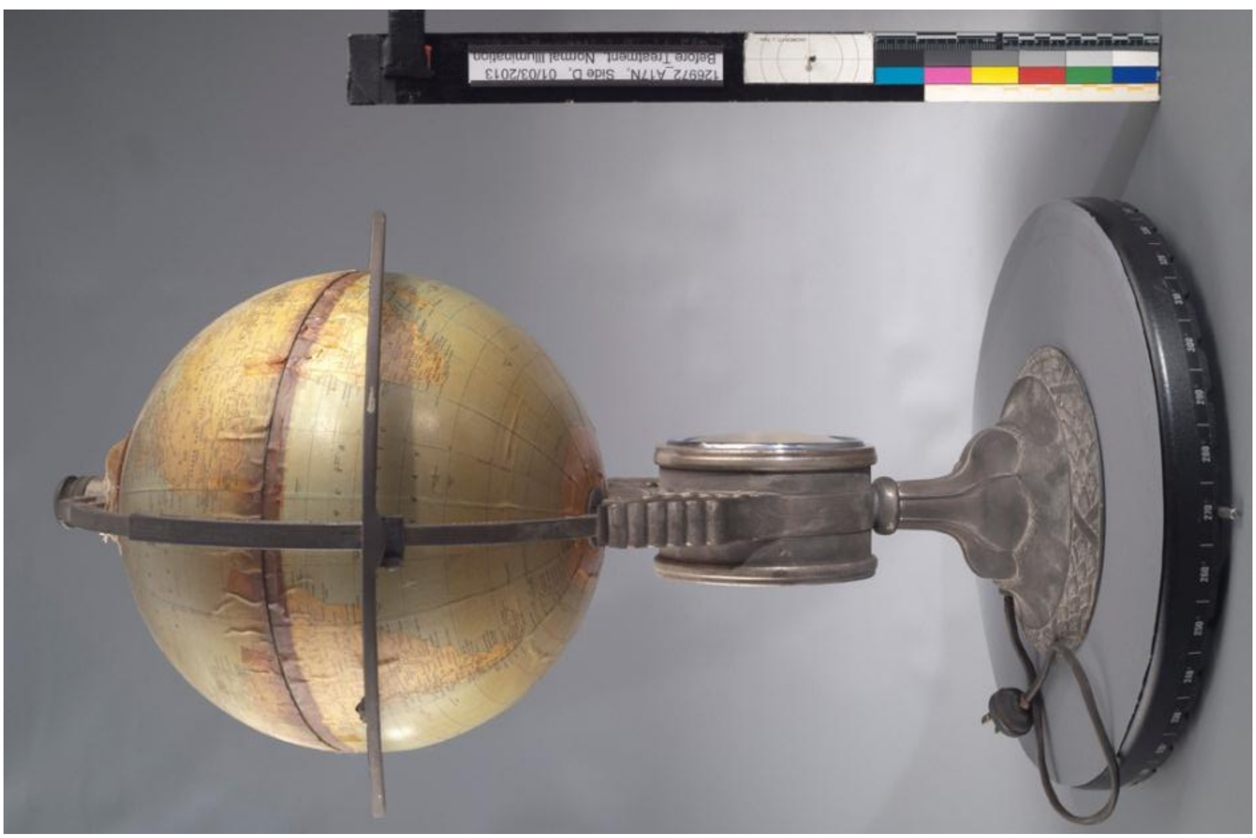


Plate 9: *Proper right, before treatment, normal illumination*

Plate 11: *Top, before treatment, normal illumination*

Plate 12: *Top, after treatment, normal illumination*

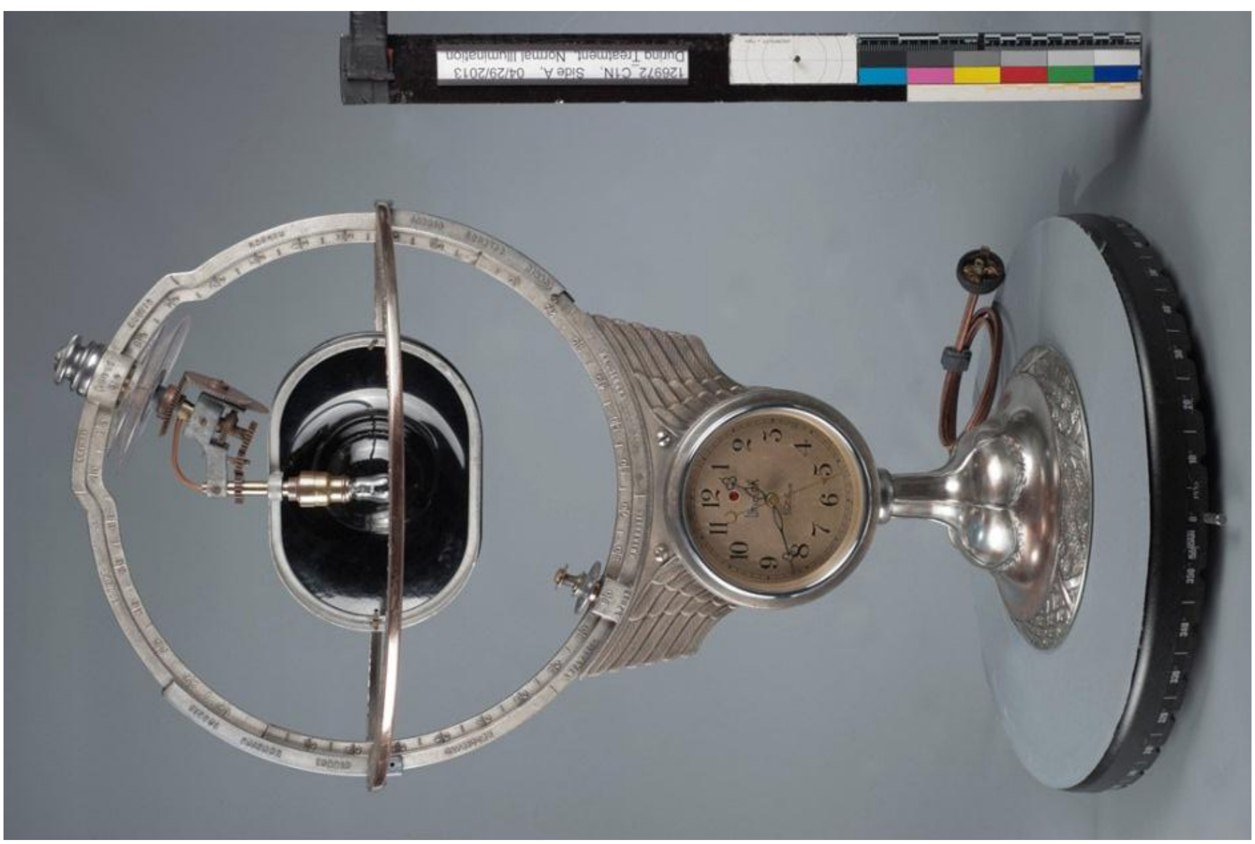


Plate 13: *Front with globe hemispheres removed, during treatment, normal illumination*

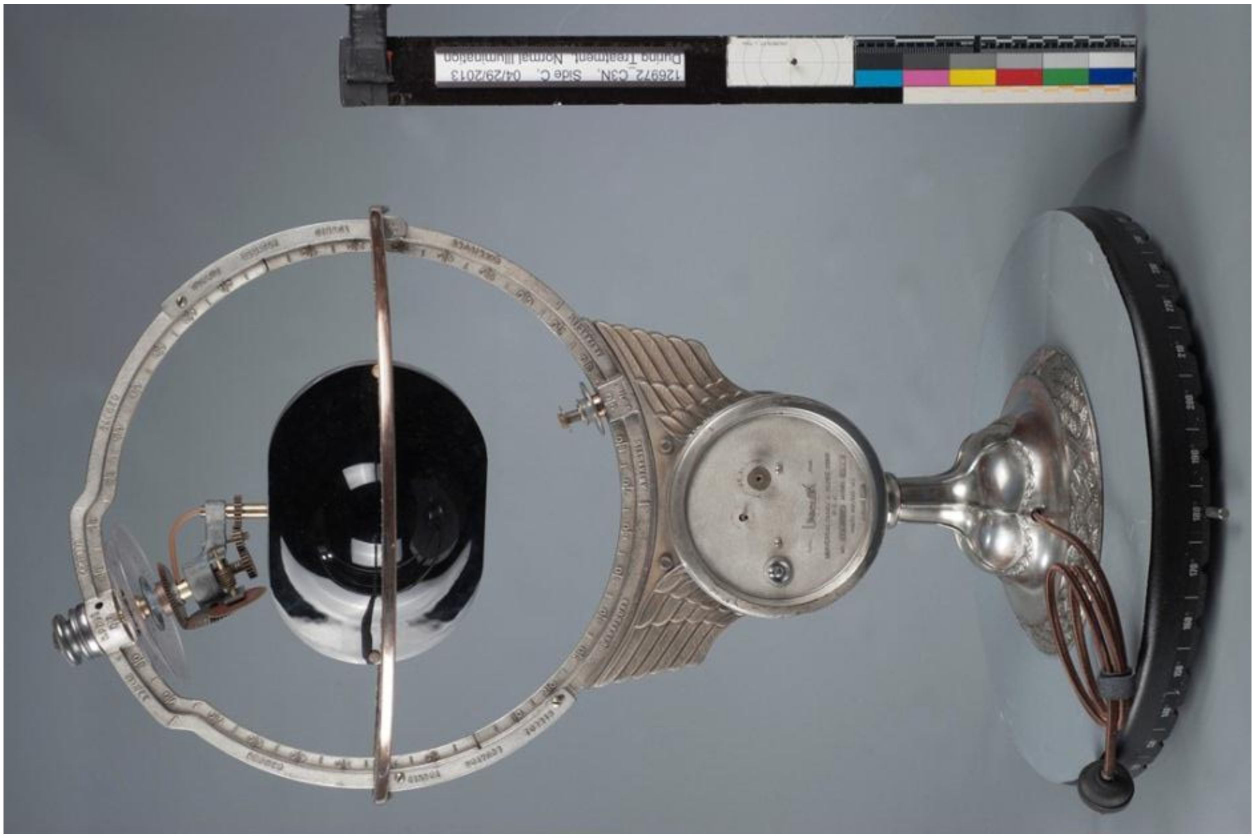


Plate 14: *Back with globe hemispheres removed, during treatment, normal illumination*

Plate 15: *Front, after treatment, transmitted illumination*

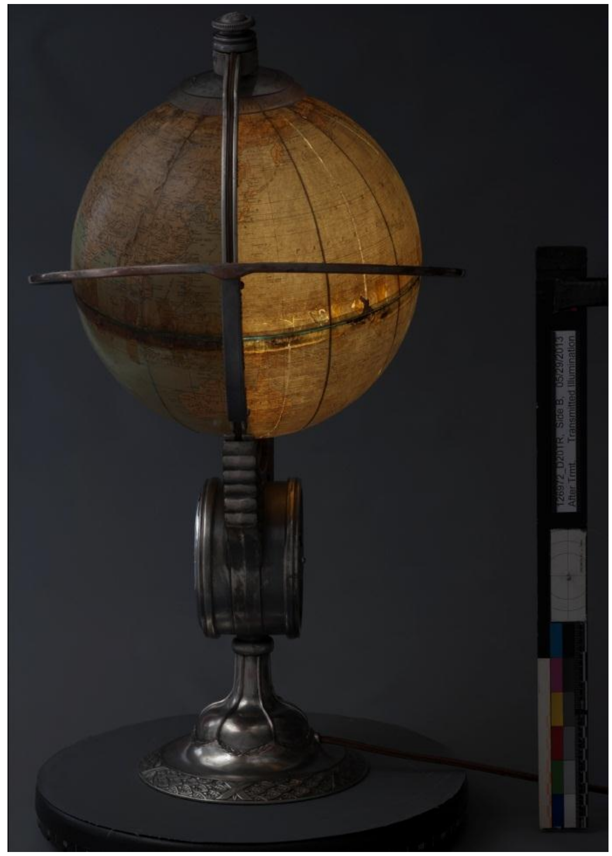


Plate 16: *Proper left, after treatment, transmitted illumination*

Plate 17: *Back, after treatment, transmitted illumination*

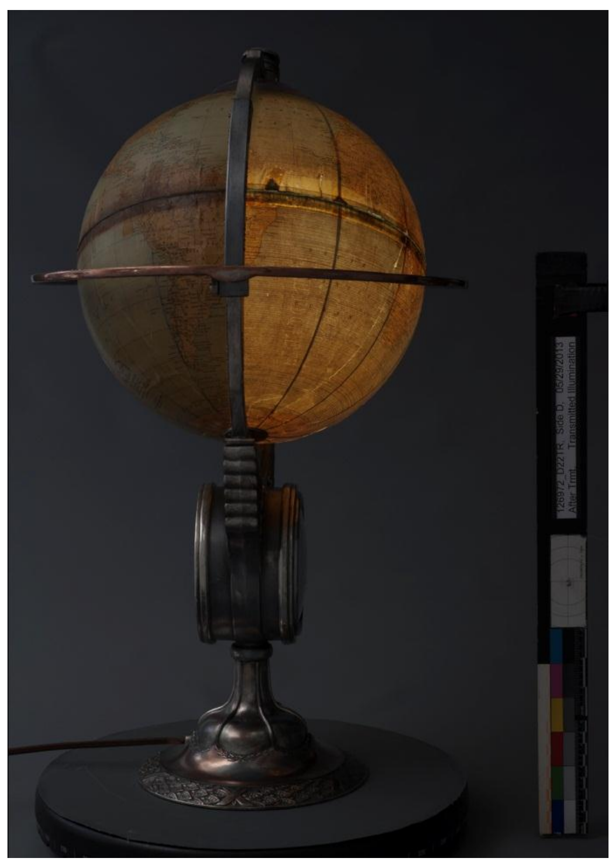


Plate 18: *Proper right, after treatment, transmitted illumination*

15. Appendices

15.1 Appendix 1: Fourier Transform Infrared Spectroscopy Settings

Attenuated Total Reflection (iTR ATR) FTIR Spectroscopy

Infrared spectra for samples of the calotte, light shade and globe materials were collected using a Nicolet 6700 FTIR spectrometer (Thermo Scientific) with a Thermo Scientific Smart iTR ATR accessory. Samples were analyzed by pressing them against the diamond ATR crystal. Each spectrum collected was the average of 16 scans at 4 cm^{-1} spectral resolution. An ATR correction routine was applied to compensate for variations in penetration depth with wavenumber. Sample identification was primarily achieved by comparing ATR spectra of the sample to spectral libraries of common conservation and artists' materials (Infrared and Raman Users Group, http://www.irug.org) using Omnic 8.1.11 software (Thermo Scientific).

15.2 Appendix 2: Gas Chromatography - Mass Spectrometry Settings

A sample of the nitrocellulose globe was analyzed by Py-GC-MS. A Frontier Lab Py-2020D double-shot pyrolyzer system was used for pyrolysis, and the pyrolysis interface was maintained at 320 ^{o}C. The pyrolyzer was interfaced to an Agilent Technologies 7820A gas chromatograph coupled to a 5975 mass spectrometer. An Agilent HP-5ms capillary column (30 m x 0.25 mm x 0.25µm) was used for the separation with He as the carrier gas set to 1 mL per minute. The split injector was set to 320 ^{o}C with a split ratio of 50:1 and no solvent delay was used. The GC oven temperature program was 40 ^{o}C for 2 minutes, ramped to 320 ^{o}C at 20 ^{o}C per minute, followed by a 9 minute isothermal period. The MS transfer line was at 320 ^{o}C, the source at 230 ^{o}C, and the MS quadropole at 150 ^{o}C. The mass spectrometer was scanned from 33-600 amu at a rate of 2.59 scans per second. The electron multiplier was set to the autotune value. Samples were placed into a 50 µL stainless steel Eco-cup. An Eco-stick was fitted into the cup, and was placed into the pyrolysis interface where it was purged with He for 3 minutes. Samples were pyrolyzed using a single-shot method at 550 ^{o}C for 6 seconds. Sample identification was aided by searching the NIST MS library.

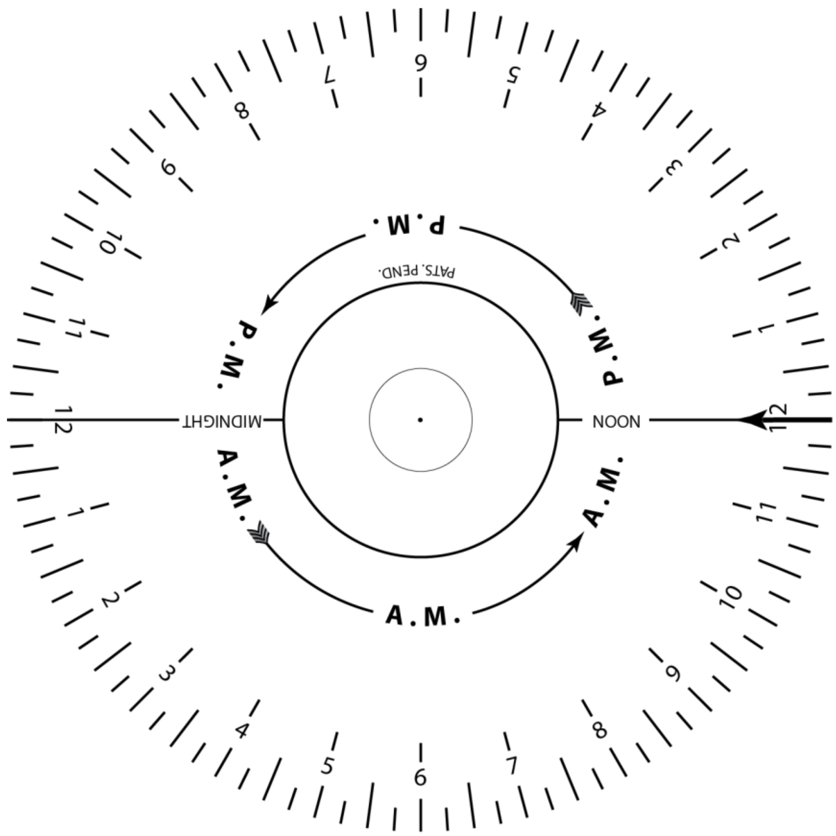
15.3 Appendix 3: X-ray Fluorescence Spectroscopy Settings

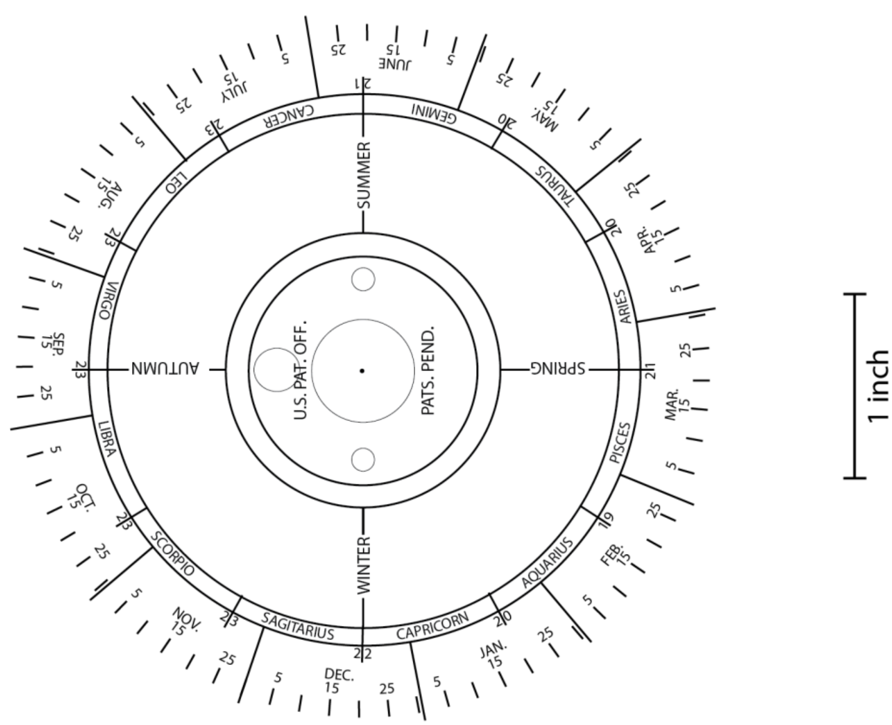
X-ray fluorescence spectra were collected using a Bruker Artax 400 energy dispersive X-ray spectrometer system. The excitation source was a Rhodium (Rh) target X-ray tube with a 0.2 mm thick beryllium (Be) window, operated at 40 kV and 1000 μA current when detecting heavier elements and 15 kV and 1200 μA current for lighter elements . The X-ray beam was directed at the artifact through a collimator 1.0 mm in diameter. X-ray signals were detected using Peltier cooled XFlash silicon drift detector (SDD) with a resolution of 146.4eV. Helium purging was used to enhance sensitivity to light elements. Spectral interpretation was performed using the Artax Control software. The spectra were collected over 90 seconds (live time).

15.4 Appendix 4: Spectral Power Distribution Curves for Replacement Light Sources

A spectrophotometer was used to test the appropriateness of two consumer-ready LED light sources and two standard incandescent indicators to replace the burnt out incandescent bulb that came with the Uniclok globe. In each case the bulb was screwed in to a night light holder, plugged in to a 120V mains outlet, and angled such that it shone with maximum intensity at the spectrophotometer set in to the head of the Oriel Micro-fading Tester. The output of each bulb was captured by a Control Development Diode Array Spectrograph and interpreted and presented as a spectral power distribution (SPD) curve using Spec 32 software (version 1.5.6.9). The shape of each curve was used to determine the bulb's suitability for the project.

15.5 Appendix 5: Digital Recreations of the Time and Date Calottes





15.6 Preventive Conservation Recommendations

The Uniclok globe is composed of a variety of materials, some of which degrade to produce pollutants that can be deleterious to the object itself and other items in the museum collection. The ideal storage scenario for the Uniclok object would involve good air exchange and/or the use activated carbon pellets to reduce evolved acetic and nitric acid vapors. Activated carbon impregnated with either potassium hydroxide or potassium carbonate has the best broad spectrum absorption of acetic acid and nitrogen dioxide compared to other pollutant scavengers like zeolites. Placing A-D Strips (developed by the Image Permanence Institute) in the vitrine or storage box would provide a means of visually monitoring for the evolution of acidic vapors, as could the use of sulphonephthalein indicators. Most importantly, the object should be segregated to minimize the potential for its innate acidic vapors to harm other objects in the collection, especially metals and other cellulose-based artworks.

Ideally the artwork should be kept in cool storage at approximately 45% relative humidity (RH). This would slow the aging and decay of the plastic components and also the speed at which the silver tarnishes. Care should be taken to not lower the RH below 40% where the paper gores could start to experience mechanical damage due to an undesirable decrease in moisture content.